MICHIGAN

SCHOOLMASTERS' CLUB

Proceedings

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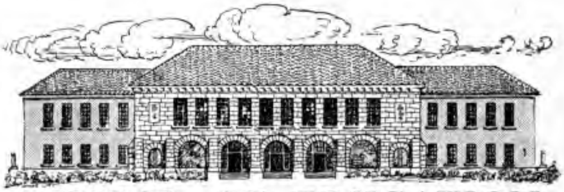

PROCEEDINGS

OF THE MICHIGAN SCHOOLMASTERS' CLUB AT THE THIRTY-SECOND MEETING HELD IN YPSILANTI MARCH 31 AND APRIL 1, 1899

Report of the Ph[y]
Conference.

Ann Arbor
University of M
1899

MICHIGAN SCHOOLMASTERS' CLUB.

PROCEEDINGS OF THE THIRTY-SECOND MEETING, HELD AT YPSILANTI, MARCH 31 AND APRIL 1, 1899.

CONFERENCE IN PHYSICS.

MARCH 31, 1899.

PRELIMINARY NOTE.

Some six years ago those members of the Michigan Schoolmasters' Club who were interested in the teaching of physics determined to form a conference for the more systematic study and discussion of topics immediately connected with that branch of science. Of necessity much attention was devoted to laboratory work and methods; teachers of physics throughout the state were urged to bring to the conferences pieces of apparatus which they had found specially efficient and useful; new devices and improved forms of laboratory apparatus received special consideration, while the spirited discussions and the increased interest and efficiency in the teaching of physics in the high schools warmly attested the wisdom of the new departure. Of the many excellent contributions presented at the sessions of the conference some have been printed in the various scientific and educational journals; some by private subscription, and others are yet to appear. It has been felt, however, that the proceedings of the Conference were worthy of publication as a whole, and the present volume contains the papers presented at the meeting in Ypsilanti, in April, 1899. To the proceedings of this meeting has been added the report of the committee appointed by the Conference in March, 1897, to prepare a list of forty problems for the physical laboratory. This report was submitted to the Conference at its April meeting, in 1898, and after extended discussion adopted, and the list of problems recommended to the high schools of Michigan as suitable laboratory practice for students of physics in the secondary schools, and for those preparing for college or the University. The work of the Conference at its Ypsilanti meeting was chiefly devoted to the discussion of the first twelve problems of this list.

Finally, there have been added a bibliography of physics, two lists of apparatus suitable for the physical laboratory and two papers upon the teaching of physics in the secondary schools, which it is hoped may prove helpful to those engaged in this work.

JOHN O. REED,
Chairman of Conference for 1899.

COMMITTEE'S REPORT.

Report of the Committee appointed by the Physical Conference of March, 1897, to Prepare a List of Forty Problems for the Physical Laboratory:

A. Refers to Adams' Physical Laboratory Manual.
C. Refers to Chute's Physical Laboratory Manual.

MECHANICS.

1. The Jolly Balance (A. iv.).
2. Composition of Forces (A. x, xi; C. 30, 31. 32).
3. Laws of Accelerated Motion (A. xiii; C. 34).
4. Laws of the Pendulum (A. xiv, xv; C. 35).
5. The Lever (C. 36).
6. The Inclined Plane (A. xvi; C. 39).
7. Pressure in Liquids (A. xvii, xviii, xix; C. 40, 43).
8. The Siphon (C. 45).
9. Boyle's Law (A. xxi; C. 44).
10. Archimedes' Principle (A. xxiii; C. 46, 47).
11. Density of solids (A. xxiv, xxv; C. 48, 49, 50, 51).
12. Density of Liquids (A. xxvi, xxvii, xxviii; C. 52, 53, 54, 55).

HEAT.

13. Fixed Points on a Thermometer (A. xxix; C. 58).
14. Coefficient of Expansion (A. xxx, xxxi; C. 63, 64, 65).
15. Specific Heat (A. xxxii; C. 69, 70, 71).
16. Latent Heat of Fusion of Water (A. xxxiii; C. 73).
17. Latent Heat of Vaporization of Water (A. xxxiv; C. 74).

MAGNETISM.

18. Curve of Magnetization (C. 79)..
19. Mapping Magnetic Fields (A. xxxvii, xxxviii; C. 80).

ELECTRICITY.

20. Simple Voltaic Cell (A. xxxix; C. 84).
21. Action of Current on Needle (A. xl, xli; C. 85).
22. Electromotive Series (A. xlii; C. 86).
23. Resistance of Conductor (A. xlviii; C. 89, 90).
24. Resistance of Batteries (A. l; C. 91, 92, 93).
25. Fall of Potential in Conductors (A. xlvii).
26. Electro-motive force of a Cell (A. xlix, li; C. 96, 97, 98).
27. The Tangent Galvanometer (A. xliii, xliv; C. 94, 95).

SOUND.

28. Velocity of Sound in Air (A. lvii; C. 104).
29. Velocity of Sound in Solids (Kundt) (A. lviii; C. 105).
30. Law of Length for Strings (A. liii; C. 110).
31. Law of Diameter for Strings (A. liv; C. 111).
32. Law of Tension for Strings (A. lv; C. 111).

LIGHT.

33. Photometry (A. lix, lx; C. 115).
34. Law of Reflection (A. lxi; C. 117).
35. Measurement of Angle of Prism (A. lxxi; C. 118).
36. Image in Plane Mirror (A. lxii; C. 119).
37. Focal Length of Concave Mirror (A. lxii; C. 120, 121).
38. Index of Refraction of Water (A. lxx; C. 126).
39. Index of Refraction of Glass (A. lxxii; C. 127).
40. Focal Length of Convex Lens (A. lxiv, lxv; C. 128, 129, 130).

SESSION OF FRIDAY AFTERNOON.

The meeting convened at 2:30 p. m., called to order by Professor John O. Reed of Ann Arbor, Chairman, who announced the order of business for the day, appointed a committee on nomination of officers for the ensuing year and then passed to reading of the papers upon the program.

PAPERS AND DISCUSSIONS.

NOTES ON THE DETERMINATION OF DENSITY.

BY PROFESSOR E. A. STRONG, YPSILANTI.

[ABSTRACT].

If we define density as the mass in grams of one cubic centimeter of the substance under consideration, the fundamental determination of density implies the determination of volume and mass.

For solids, the volume of which may be found by geometrical methods, it is sufficient to use the same parallelopipeds, cylinders and spheres as have been already measured in fixing the relation of the cubic inch to the cubic centimeter, and weighed in getting an expert use of the balance.

For irregular solids there is no good volumenometer of simple construction and easy use. Paalzow's, Hartl's and Niemoeller's were exhibited and discussed.

This first step is often omitted, but this omission implies a different concept of density.

The second step is the proof of Archimedes' principle and its application to the determination of density. Here a balance for each student is essential, and at least one standardized set of weights. If a beam-balance is used the students' sets of weights, with table of corrections and the value in milligrams of each scale division of the pointer, may be employed, as determined in the earlier work upon the balance. If a Jolly balance is used the table showing the value of each scale-division in mg. which was worked out by the pupils in earlier experiments will render a set of weights unnecessary.

Other forms of balance were discussed to show the possibility of avoiding the expense of time and money inseparable from the use of the beam-balance and the small range of the Jolly form. The speaker's preference was for the beam-balance over all forms, except in rapid expert use, where the one-arm balance has obvious advantages.

A wheel-balance, Fig. 1, was exhibited, and it was shown that while

poorly adapted to general use it was admirably fitted for the proof of Archimedes' principle, the demonstration of the doctrine of moments, and of the relation between the principle of the lever and that of the inclined plane.

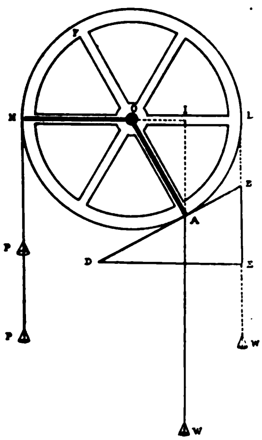

FIG. I.

The scale-pan, W, and the counterpoise, P, each weighing one gram, are attached to opposite ends of a diameter, A F, which is horizontal when no additional weight is placed in the pan. The counterpoise rises vertically as the pan slides down the arc of a circle, moving at any point, as at A, in the tangent, D B, and acting upon the effective lever-arm I O. The weight is to the power as H O is to I O, or as AO is to I O, or as D B is to B E. A mirror and millimeter scale are placed behind the filaments of suspension. The balance may be made direct-reading or not, at pleasure.

A torque balance was also exhibited and discussed. For certain chosen weights such a balance may be made extremely sensitive with large load, but it can never answer the purposes of a general balance.

Nothing new was brought out in the discussion of methods of finding the density of light and finely divided solids. The sinker and the pyknometer methods leave nothing to be desired. The press of matter is so great in the experimental course that the use of the balance should either be taught along with the density work, or the materials to be used in this work should be weighed while teaching the use of the balance. The total number of experiments in the density determinations need not exceed five, including the work with Nicholson's hydrometer, which was strongly commended.

For the density of liquids it is well to use both the sinker method (a piece of glass rod drawn out at one end and turned into a hook) and the pyknometer method. For the latter, it is sufficient for students' practice to weigh the pyknometer; fill with the liquid to be determined, wipe and weigh; pour out and rinse two or three times with clean water, and finally fill with water, wipe and weigh again. Thorough drying is tedious and unnecessary. A pipette holding two cubic centimeters was strongly commended as a pyknometer.

The density of gases, or weight in vacuo, is rarely attempted in a students' course, owing to want of time.

Archimedes' principle in its application to gases deserves more attention than it usually receives.

The following references may be consulted, in addition to the practical manuals.

Pyknometers:

Ostwald, Physico-chemical Measurements, pp. 90-94.

Volumenometers:

Overbeck,— *Wied. Annalen* 1899 p. 209.
Paalzow,— *Wied. Ann.* 1881, p. 332.
Ruedorff,— *Wied. Ann.* 1879, p. 228.
Niemoeller,—*Zeitschrift f. Physikal. u. chem. Unterricht*, Vol. 8, p. 39. Vol. 9, p. 240.
Hartl,—*ibid*, Vol. 8, p. 207.
Vol. 11, p. 280.

THE CAPILLARY BAROMETER.

BY MR. L. F. MILLER, ANN ARBOR.

The following paper contains the results of some investigations conducted under the direction of Dr. Guthe upon the capillary barometer. This form of barometer is not new, it having been first investigated and described by Melde.

The aim of our investigation has been to so simplify the instrument and systematize its use, as to render it a practicable instrument for use in the high school. A cheap, reliable barometer is at present much needed in our secondary schools.

FIG. 2.

The principle involved in the use of the capillary barometer is that of Boyle's Law, viz., the compression or expansion of an enclosed volume of air at constant temperature caused by increasing or decreasing pressure. The instrument consists of a capillary tube, Fig. 2, closed at one end and open at the other. Within this tube we have a volume of air A B, enclosed by a thread of mercury B C, so that when the tube stands with the open end up, the air is under the pressure of the atmosphere plus the weight of the mercury. When the tube is inverted, we still have the pressure of the atmosphere exerted upward on the volume of air, but the pressure of the column of mercury is in the opposite direction and has to be subtracted from that of the atmosphere. The tube is mounted with a scale back of it so that the volume of the air and length of the mercury column may be read off directly.

The relations may be stated as follows: Let

B = the pressure of the atmosphere in centimeters of mercury.
h_1 = the length of the mercury column when instrument is erect.
h = the length of the mercury column when instrument is inverted.
v_1 = volume of air when instrument is erect.
v = volume of air when instrument is inverted.

The weight of the mercury column being constant, its length would be the same in both positions of the instrument, that is, $h = h_1$, if the glass tube were of uniform bore. The formula would then be

$$\frac{v_1}{v} = \frac{B - h}{B + h}$$

$$\text{or } B = \frac{v + v_1}{v - v_1} h$$

But we must take into account the variation in length of the mercury column due to a variation in the bore of the tube and we have

$$\frac{v_1}{v} = \frac{B - h}{B + h_1}$$

$$\text{or } B = \frac{v h + v_1 h_1}{v - v_1}$$

$$\text{or } B = \frac{v + v_1}{v - v_1} \frac{h + h_1}{2} + \frac{h - h_1}{2}$$

a more convenient form for computation.

The irregularity in the bore of the tube also affects the volumes v and v_1 and it is therefore necessary to calibrate the tube. This is done by taking a short thread of mercury of known length and moving it along the tube at stated intervals of measurement and noticing the variation in the length of the column. A curve is then plotted in which the stated intervals are taken as abscissæ and the corresponding variations in length as ordinates. This gives a curve of corrections for the readings of volumes of air.

The following results obtained from two different instruments give some idea of the accuracy obtainable:

CAPILLARY TUBE NO. 1.

Diameter between 1.5 and 2.0 mm.

B. *Observed.*	B. *Standard.*
747.9	747.6
748.3	748.7
729.8	729.8
729.4	731.7
745.7	747.6

CAPILLARY TUBE NO. 2.

Diameter 2 mm.

B. *Observed.*	B. *Standard.*
735.5	735.7
747.1	747.3
743.1	743.4
746.3	746.3
743.4	743.2
729.9	729.8
725.3	726.0
727.0	727.6

It will be observed that the first tube did not give as good results as the second; this is probably because it has too small a bore, the capillary attraction reducing the sensitiveness of the instrument. On the other hand, if the bore is too large, the mercury column is apt to separate. Therefore a medium diameter (about 2 mm.) should be chosen. One might think that this barometer, since it has no vernier, would not give very accurate readings, but the fact that we take four readings to obtain B from the formula should make it quite possible to obtain in the average, a result correct to two or three-tenths of a millimeter, which is sufficient for all practical purposes. Another part of the instrument that should be noticed is the plug. This should fit air-tight, and the inner end should be square cut.

There are several interesting principles to be brought out by this instrument. If it be turned from the erect position to the inverted position for a few minutes and then returned to its original position, the volume of air will read less than it did at first, because expanding the air mechanically cools the gas so that the volume under the original pressure becomes less. Boyle's Law is also illustrated by this instrument.

In making the barometer the tube must be thoroughly cleaned. The cleanest tubes are those that are obtained directly from the factory. Dirt quickly accumulates in tubes which lie in stock. The most difficult part in the construction of the barometer is the calibration of the tube; it must be done accurately. When I had finished the last instrument I found that there was a constant error of about three millimeters in my results. I examined the theory, the effects of temperature and many other things, but could not account for the error. But here we see the effect of the personal equation, for finally by using a long column of mercury, I found that there was a cumulative error of about three millimeters. The calibration had been done with a short column and each time the reading was taken a little too large, so that at the end the error amounted to considerable. However, if the instruments were to be manufactured a simple apparatus for calibration could be constructed which would eliminate all personal errors. With all these precautions the capillary barometer seems worthy of recommendation for high school purposes. The cost for material is slight and the only difficulty is that the construction requires some practice and skill.

QUESTION: Do you dry the enclosed air? A: Yes, sir; that is, we heat the tube before enclosing the volume of air.

Q. How do you put the mercury into the tube? A. Having prepared the plug and fitted it, I mount the tube in a horizontal position with supports, insert the mercury into the right position and then seal the plug into the end.

Q. What is the plug you use in the tube made of? A. Steel; I used glass once and it did very well, but steel is better.

EXPERIMENTS IN VIBRATION.

BY MR. F. R. GORTON, YPSILANTI.

The apparatus which I shall use is neither new nor ingenious, but what it lacks in newness and ingenuity, it will make up in size.

I bring out first this large tuning fork, which can be made by any blacksmith. It is mounted on a heavy base and is quite permanent. I also use this rotator which has attached to it a wheel containing sectorial openings. The fork is used because it admits of greater amplitude than most forks. The purpose of the experiment is to render the separate vibrations of the tuning fork entirely visible. If the rotator with the disk is placed in front of the tuning fork the class can see through these openings as the wheel is rotated, watch the prongs of the fork and can see the fork in vibration. Now, if I turn with the proper rapidity the prongs seem nearly to stop vibrating, and one can see them as they move in and out. If I turn the wheel with proper speed, those prongs will seem to come absolutely to rest. But since we want to show the relative motion in the prongs of the fork, we do not turn it quite so rapidly. Thus the prongs can be seen while moving.

This is a very simple way of enabling the student to see the kind of vibration that is going on in the tuning fork. The same apparatus may be used for some experiments known as the Melde experiments. In general, the ordinary tuning fork is one that vibrates so rapidly and has so small an amplitude that

it could not have much effect upon a cord large enough to be seen by the whole class; but this fork will admit of such a cord. So I have arranged this cord with a weight at the other end. I am not able to go into the whole matter here, but we can make use of this experiment to show what is meant by the node and the segment. Perhaps the cord vibrating in a horizontal plane does not show exactly what it is doing, but if one looks down on it from above or gets under it and looks up at it in a perpendicular plane, it is seen to be divided into two equal segments and there are stationary nodes. If I put on a different weight, we get a different number of segments. I get now four segments having three nodes, and from that we can get the idea of how nodes and segments are formed. These weights, on examination, are found to be in such relation to each other as to verify the law of tensions so that by means of this system and the series of weights, we can verify the well-known law of tensions, viz., that the number of vibrations varies directly as the square root of the tension on the string.

There is one piece of apparatus which is not of great importance but which I shall show. I have two organ pipes which form the second and third notes of the major scale. This one which gives the higher note is arranged with a paste board tube to slide up and down the pipe. By elongation the pipes can be made to give exactly the same pitch. By a slight change in the length of the sliding tube, we change the pitch, so that when sounded together they give beats that can be distinctly heard all over this part of the building. It may be useful to some who have several organ pipes.

This matter of nodes and segments called to my mind an experiment which I found in some of the books sometime ago, not an ordinary text-book, however,—an experiment for finding nodes in a tuning fork. I have lost a part of my apparatus so that I cannot go through it now. It was simply a cube of wood. I will explain briefly how it can be done. Is it a fact that we can locate nodes in a fork? It may seem impossible for these heavy prongs of steel to divide into segments as this string divides, but it is possible,—part vibrating one way and part another, so that by clamping it upon the table, one by bowing it near the end can make it sound its fundamental tone. But by bowing it about one-third of the way to the end, it can be made to sound a tone very much higher than the fundamental tone; by bowing it still nearer the shank one can make a very shrill tone, and by sprinkling sand upon the prongs of the fork, the node or nodes can be located plainly showing that the prong divides into segments,— these points in that heavy prong being approximately stationary.

I have been looking through several works on elementary physics and I find they are about all alike. Almost invariably I find this statement in the text, that if you pluck a string of the sonometer near one end, it vibrates, not only as a whole, but also in parts. But that needs to be demonstrated, and I have yet to find in any text how we can prove to our satisfaction that this is the case. We require an experiment that will enable us to analyze a compound tone so as to prove that the string really divides into parts at the same time that it vibrates as a whole. For this we are generally referred to the experiments with the Helmholz resonators. Now resonators are not commonly found. But we have a method by which we can analyze a compound tone. Besides if you have resonators you have to be able to detect the presence or absence of re-enforcement of the sound. But the sonometer will enable me to show you that fact, which is stated in the text-books, that when I pluck the string near one end it vibrates in parts as well as a whole.

I put two wires in unison. They then vibrate sympathetically. If one is sounded the other one begins to vibrate and gives off a tone of its own. All you have to do is to put a rider of paper on the wire and the fact that the rider jumps from the wire shows that it is vibrating. That simply demonstrates to us that those wires which are in unison vibrate sympathetically. If we are in doubt as to whether they have to be in unison, we put them out of unison and the experiment fails. But suppose I put this bridge in the middle; the wire will give a note an octave higher. Now I pluck this in the center. The rider shows no indication of the sympathetic vibration. But if I pluck near one end, the rider jumps from the wire. That string which is capable only of vibrating sympathetically does vibrate in that manner when I pluck this one near the end; but it must be vibrating with the string which is in unison with it. So we have separated in that way this important overtone, among all the overtones which accompany the fundamental. Suppose I put the bridge one-third of the distance from this end; the fact that the rider jumps from the wire shows that the string not only vibrates as a whole, but that it divides into three equal parts, so that besides the fundamental which you hear, there is a note which has three times as many vibrations as the fundamental.

Another point is, that if we pluck this wire here even with the point at the bridge, we find that the other does not vibrate, showing us that if the string is bowed at a point where there would have to be one of these nodes, the overtone is not present, because it does not vibrate. Now, if I put this one-fourth of the distance from this end, the rider jumps off as before, and I have plucked it at the same point. The fact is this string vibrates as a whole and in two, three or four parts at the same time. It divides readily also into five parts, or any other number.

Now I will place these riders on here again and close the whole experiment by this particular part of it, which will show us how readily a string of the sonometer can divide itself into parts. I have placed here in the middle a rider; the bridge is one-fourth of the way from the end; three-fourths of the way from the same end another rider is placed, and between them three more; then I pluck the other wire, and the fact that these riders jump off shows us how easily this string divides into parts, showing the exact location of the nodes.

THE JOLLY BALANCE.

BY MR. C. F. ADAMS, OF DETROIT.

In my experience I have found the following exercise with the Jolly balance most admirably adapted to introduce the student to the more serious work of the laboratory. In our school this exercise is the first, following a few exercises in simple measurements. It is a most valuable experiment in itself, and it prepares the pupil for using the balance for weighing in the work that follows.

A discussion of the following table, which contains the data obtained by one of our pupils, will make clear the method used in this exercise:

BALANCE NO. 10.		SPRING NO. 10.		MODULUS 1.156.	
Reading without Load.	Average without Load.	Reading with Load.	Load.	Elongation.	Elongation per Gram.
45.5 c. m.					
45.5 "	45.5	41.2	5g.	4.3 c. m.	.860
45.5 "	45.5	36.8	10	8.7 "	.870
45.5 "	45.5	32.5	15	13.0 "	.867
45.49 "	45.495	28.15	20	17.355 "	.867
45.47 "	45.48	23.85	25	21.63 "	.865
45.45 "	45.46	19.5	30	25.96 "	.865
45.42 "	45.435	15.2	35	30.235 "	.864
45.40 "	35.41	10.65	40	34.76 "	.869
45.35 "	45.375	6.7	45	38.675 "	.860
45.36 "	45.355	2.3	50	43.055 "	.861

Average elongation per gram............................ .865
Number of grams required to cause an elongation of 1 c. m., 1.156,

The readings of the first column are taken both before placing each weight or load in the pan of the balance and after each weight is removed; but the reading taken after removing a weight serves also for the reading to be taken before the use of the next weight. The second column contains the average of the two readings, that taken before and that taken after the use of each load. The fifth column gives the elongation of the spring in centimeters. These numbers are of course obtained by taking the difference between the numbers in columns two and three.

The last column contains the quotient of the elongation by the load. It will be observed that this quantity is a constant or nearly constant quantity. The student should now be taught the significance of this fact. He should learn the mathematical principle that when the quotient of two variables is constant the two quantities are directly proportional, and he should be able from this time on to use this principle in his laboratory work. In as much, however, as the quotients are not exactly constant the pupil should account for the discrepancies before being allowed to affirm the proportionality of the two quantities. Just here this exercise affords excellent material for the discussion of the subject of errors. Errors must occur in laboratory work, and they should not be ignored. I know of no exercise better adapted to introduce the pupil to the subject of errors than this.

By finding the average of the last column and taking the reciprocal of that average the number of grams required to elongate the spring one centimeter is obtained. This is termed the *modulus* of the spring and is to be used by the pupil in later experiments in weighing by the Jolly balance.

This exercise affords one of the best illustrations of a simple physical law, a constant relation between two dependent phenomena. The law in this case, Hooke's law, is a very important one, and one which it seems to me should receive more attention in physics in the high school, especially in its relation to simple harmonic motion.

The exercise is a study in elasticity and illustrates the principle of the common spring balance. This exercise is ideal as a first exercise for the pupil in plotting curves. It is also a most excellent experiment with which to begin note book work. Incidentally the pupil learns from this exercise what *parallax* is and how it may be avoided. All in all, this experiment, as I said at first, is a most useful one as an introduction to laboratory methods.

QUESTION.—Do you not think it worth while to change the spring so as to make the last column 1? A. As a laboratory exercise I should prefer not to have it exactly 1, and practically it would seem to me very difficult to make it accurately so, and not scientific to try it. Q. How heavy a wire do you use for a spring? A. From No. 22 to No. 24 brass wire.

A MODIFICATION OF THE JOLLY BALANCE.

BY MR. R. B. DEAN, PONTIAC.

We have already listened to an explanation of the use of the Jolly balance and heard its limitations detailed, and I think it has its place in laboratory work. Mr. Miller suggested that we never have at our command all the money we wish for, and in casting about for a modification of the Jolly balance which would be satisfactory for all our purposes, we hit upon the apparatus I wish to present here. We find it serviceable in meeting the requirements of the Jolly balance. In Fig. 3 we have the same instrument we are using in our school at present; it consists simply of an oak frame with the mirror scale MM, ruled in half millimeters. The support for the springs is, as you see simply the rod B held by the spring clamp A, the same as that used on doors to open and close the transom.

Now a word in regard to the making of this Jolly balance. I went to the planing mill and had the oak supports grooved, and I found I could secure the mirror with the scale upon it more easily than I could etch the rulings, so now we secure the mirrors with the rulings on them. Then all we have to do is to set this ruled mirror in the groove which we have upon our support. Then how are we to make our spring adjustable? The Jolly balances here are made so that the spring may be adjusted. I procured a transom adjuster at the hardware store and took off part of it; so you see it can be very readily adjusted to any position in which you may choose to use the spring. A word in regard to the support of this balance. The balances generally in use are supported upon a tripod. I support this balance by fastening it to the wall, as you see it here. We have upon one side of the room in our laboratory a space of twenty feet and along that side we have our Jolly balances. We have five or six in constant use.

We have made springs from different sized wires, some of No. 20, some 22 and some 24, and we have found that some interest may be aroused by having the students determine the moduli of springs made from different sized wire. Of course it is well to have a pan upon which acids do not act, though for ordinary use this is not necessary; we have found that by taking the piece of metal that is found upon the top of the cork of an ink bottle one can make a pan that is quite serviceable. You will notice

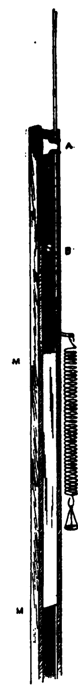

FIG. 3.

that upon this form of Jolly balance we have no adjustable shelf, but one could easily be added.

I think we have not suggested that the law of parallel forces can be demonstrated by the use of two Jolly balances. (See Adams' Manual). We have found by placing these balances at a distance of one meter apart that we can demonstrate very well the law of parallel forces. This arrangement is shown in Fig 4.

Some may be interested in the cost. We believe we have made these so that they may be had for $2.00. The mirror, graduated as it is, cost $1.50 and the transom adjuster cost 25 cents. So that we have here an apparatus that is as serviceable as any found upon the market, and one which can be placed in every high school and may be made by any one.

I think there is some advantage in having the balance fixed upon the wall. One advantage is that once having it in position it is not getting out of order; I think our students do get apparatus out of order.

QUESTION: Where do you get the glass scales? A. This we secured in Ann Arbor of Miller and Montgomery.

Q. How would it do to get your mirror in the hardware store or in a furniture store and then put on a paper scale? A. We have thought of that and it would be very much like some forms put out earlier. However, we finally decided on this plan.

Professor Strong: If I said anything against the Jolly balance I will retract it, because in the beginning it is very valuable.

Q. Is there any reason why you could not just as well buy a mirror and then clear off a strip on the back and place back of it a scale, which would answer every purpose as well? A. I think that might be done; still there is much to be said in favor of the use of this mirror. In the first place it is very difficult to clear off the back of the mirror, besides a paper scale is apt to be stretched in pasting it on and so have its length changed unequally.

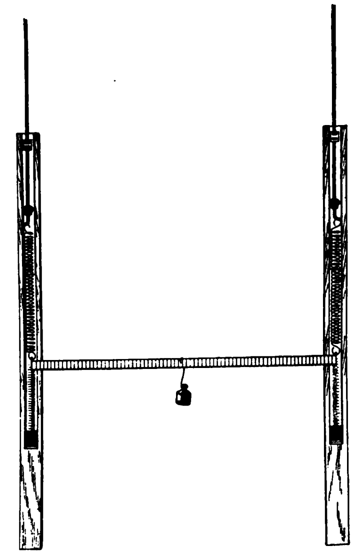

FIG. 4.

ON THE LAWS OF THE PENDULUM.

BY MR. F. A. OSBORN, OLIVET.

I have brought you nothing very wonderful or original; simply a page from a laboratory note-book, dealing with one of the most important problems in the first term of physical laboratory work. The principal features of the problem are its extreme simplicity, the fact that it requires little apparatus, and with care yields good results. The first point is the manner of suspending the pendulum. My method is to get a bracket and solder to it a binding post in a horizontal position, with the hole vertical, into this hole is placed a short piece of glass tubing so that the string will be flush with under

surface of binding post. The next point is the material for the string. I tried various kinds of string and fine wire and found all unsatisfactory; the trouble with the wire, even the finest, is that it will break off. And so the best thing I have found is silk fish cord; twenty-five cents worth will last for years. I use an iron ball two inches in diameter; when this is once put in position the stretching of the fish cord will be over in a day.

The next point with which I had difficulty was a means of measuring with some degree of accuracy the length of the pendulum, because a very slight error will throw out the value for *g*. I tried at first putting meter rods on end and measuring down to the upper edge of the ball, but in spite of all my efforts the students would stretch the string. At last I hit upon the method of mirrors. By means of a long piece of gas pipe carrying at either end a mirror scale etched in millimeters, and having one of these scales adjustable, it was possible, by placing the mirrors behind the pendulum, for two observers to take readings simultaneously upon the lower edge of the binding post and the upper surface of the iron ball. The distance between the observed scale divisions on the mirrors was then carefully measured and when increased by the radius of the ball, was taken as the length of the pendulum. Since adopting this method of determining the length of the pendulum, the results have been much more satisfactory than ever before.

The next point was the method of taking time. I tried several methods and finally used the one that is recommended by Mr. Chute in his manual, the only difference being that I doubled the number of crossings of the ball over the center line. We marked a chalk line on the floor, and when the ball crossed that chalk line on the tick of the watch we started our counts, the student counting every time the ball crossed the line, stopping the ball when it happened to cross the line at the tick of the watch. By so doing we have succeeded in getting fairly good results with this simple apparatus.

This problem, as originally assigned, used to require about two hours in the laboratory. I found a part of the difficulty was because of the hurry, and so my experience in the laboratory work led me to reduce the number of problems and to try to increase the value of the work by getting more accurate data. We now work on this problem about eight and a half hours, corresponding in my laboratory to three weeks' work. The values were obtained by two of the students, neither the poorest students nor the very best, and the actual time taken (they had had previous preparation in the work) was seven hours. I wish to call your attention to the value of *g*, which is always a difficult value to determine. The results are 976, 982.4, 974, 979, with a mean of 978. Of course in the constant, any slight error in the results would not show. The constants were 0.100, 0.100, 0.100, 0.101.

We also use this problem to show the effect of amplitude on the time of vibration, and by making the amplitude in the first case very large, say 200 cm., and in the second place very small, say 10 or 15 cm., and taking five consecutive readings, the following results were obtained. With a large arc the time of vibration was 1.484 sec., with the small arc, 1.451 sec. Then I thought it would be well to show the effect of increasing gravity, and having in the laboratory a very large permanent horseshoe magnet, I placed the magnet just under the iron ball and determined the time again. Before the magnet was used the time was 1.204 sec.; after the magnet was used it was 1.133 sec.

ON THE VERIFICATION OF BOYLE'S LAW.

BY MR. H. N. CHUTE, ANN ARBOR.

I have been asked to describe the method of verifying Boyle's Law that is used in the laboratory under my direction. The device employed, Fig. 5, is a simplification of one described in Weinhold's Physical Demonstrations. Two glass tubes, which I shall call A and B, are connected by a stout rubber tube and attached to a wooden support which can be clamped to a table. The tube A is closed air-tight by an iron cap; the tube B is open. Each tube is fastened to a wooden strip that slides freely in a groove by the side of a linear scale. An arm attached to each slider makes it possible to fasten it at any point on the scale by means of a stout pin inserted in the frame. Tube A should be of uniform bore. The rubber tube should be sufficiently heavy so as not to stretch when filled with mercury. It should be lined to prevent the action of the sulphur of the tube on the mercury. To do this, fill it with a solution of gutta-percha in chloroform. Let it stand a few minutes, then empty, and suspend in a vertical position. It is advisable to blow through the tube to prevent the solution from clogging it.

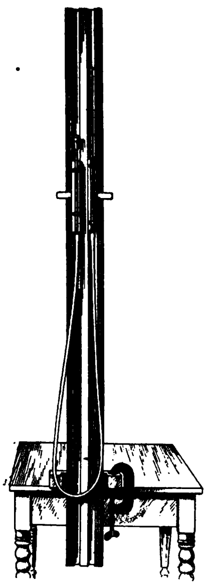

FIG. 5.

In using the apparatus, fasten A and B at about the middle of the linear scale. Remove the iron cap and introduce mercury through B by means of a funnel till A is filled about half-way up. Measure the position of the top of the tube A, on the linear scale by means of a T-shaped gauge whose arms reach across both tube and scale. Now screw on the iron cap and move the slider B up and down the scale several times, repeatedly jarring the rubber tube in order to free it as far as possible from air-bubbles. By measuring the position of the top of the iron cap on the scale, the thickness of the cap can be determined and marked on the apparatus for the pupil's use, thus making it unnecessary for him to remove the cap from the short arm.

The instrument is now ready for the pupil, who begins his work by sliding B as far down the scale as possible. This expands the air in A and also cools it. Hence, the experimenter must wait a few minutes for it to return to the temperature of the room. Advantage should be taken of this delay to read the barometer. After reading the position of the mercury surface in each tube, the tube B should be moved upward a few centimeters, and the readings again taken. This should be continued until B reaches the top of the scale.

A thermometer should rest against the tube A, and its reading should be noted from time to time to see whether the temperature remains constant. The barometer should be read frequently during the progress of the experiment as the atmospheric pressure may be changing. Since the tube A is of uniform cross-section, the length of the air column may be substituted for the volume of the enclosed air. This length is found for each trial by subtracting the reading of the mercury in A from that of the top of the iron cap, corrected for the thickness of the cap. The corresponding pressures are obtained by adding the barometric pressure to the readings

of the mercury in B and subtracting from the sum the corresponding readings of the mercury in A.

If the work has been carefully done, it will be found that the product of each air column by the corresponding pressure is practically constant. By using the air columns and the reciprocals of the pressures as co-ordinates and plotting them on cross-section paper, the points will lie in a straight line, the small deviations therefrom being due to the accidental errors of observation. Pupils will need to be cautioned against allowing their clothes to press against the rubber tube, as the slightest pressure of this kind changes the level of the mercury. The chief difficulty encountered in the use of the instrument is in making the iron cap air-tight.

Mr. Adams: I recently had correspondence with an eastern manufacturer of apparatus with regard to a form of cap for the short arm. It is so constructed that the top of the glass tube can be seen without removing the cap, and furthermore it is claimed that the cap can be manipulated safely by the pupil.

A member: Who makes it?

Mr. Adams: The Knott Apparatus Company.

Professor Carhart: I remember hearing Helmholtz tell of the way in which he filled glass tubes so as to exclude the air-film in making a standard ohm. He said that it was found possible to measure the change in resistance produced by a film of air in the tube of a thickness no greater than that of a wave-length of light. He claimed that the most effective way to remove this film of air was to use a few drops of kerosene oil.

Mr. Chute: Would not the kerosene oil in this case affect the rubber tube?

Professor Carhart: The rubber tube is lined, is it not?

Mr. Chute: Is not gutta-percha acted on by kerosene?

Mr. Andrews: How long ought the apparatus to stand after changing the positions of the arm B, to allow the air to come to the temperature of the room?

Mr. Chute: But little attention has been paid to that in our laboratory. The error due to it is undoubtedly less than most beginners can observe. Our custom is, however, to move arm B to its lowest position, and then to require the pupil to read the barometer. By the time that is done the equalization of temperature is practically secured.

Dr. Guthe: We have been using this form of apparatus this semester for the first time and it gives good satisfaction. We get into trouble, however, when we expect too much of it. If we plot the pressures on the Y-axis and $\frac{1}{V}$ on the X-axis, the straight line ought to cut the Y-axis at a distance of — P, the barometer reading, from the origin. As a matter of fact it cuts it so as to make P equal to from 760 to 780 mm. instead of 740 mm. We have not taken the instrument apart, but I presume that the error is due to a slight tapering of the tube. We have a different instrument for proving Boyle's Law for pressures less than the atmospheric pressure, and with that we can come within two millimeters.

Mr. Chute: May not the discrepancy be due to the fact that you used air from the room and not dry air?

Dr. Guthe: I do not think that would make much difference.

AN IMPROVED APPARATUS FOR TESTING BOYLE'S LAW.

BY MR. N. H. WILLIAMS, DETROIT.

Perhaps the apparatus which I am to present ought to be called a modified rather than an improved form, as I do not wish to claim too much for it. Not long ago I visited a high school and the instructor in physics showed me a piece of apparatus similar to that just described by Mr. Chute. He told me that he had consumed all the mercury in the building in making the one piece. The apparatus we are now to consider has this advantage at least, that it requires less mercury than the other, is much less expensive, and can be made in half an hour.

One of the forms of the apparatus in its process of evolution is shown in Fig. 6. It is extremely simple. An inch hole is bored though a small block of wood, F; this hole is fitted at one end with a double bored stopper and with a single bored stopper at the other. The two tubes A and B are inserted in the double bored stopper. A is open at the top and B is closed. The single bored stopper is fitted with a glass tube to which is fastened a rubber tube with a pinch cock, E. Mercury is poured into the tube A until the space in the block F is filled, then the tubes are held in a horizontal position to allow some of the air to escape from B. The air column should be about fifteen cms. long. The block is then clamped to the Jolly balance and the tube A is filled with mercury by means of a small funnel. The readings are taken from the scale of the Jolly balance and the variations of pressure are produced by allowing a little mercury to flow out after each reading is made. See Fig. 7.

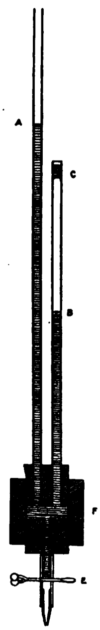

FIG. 6.

The apparatus has been developed a little farther to meet the objection that it is hardly best to have the student handle the mercury. This objection is met by having the third tube pass through the upper stopper instead of through the lower one, and by allowing air to escape instead of allowing mercury to flow out. This makes the lower stopper unnecessary, so that a small bottle may be substituted for the block; The apparatus then takes the form shown in Fig. 8. The tubes A and B pass to the bottom of the bottle, while the third one merely passes through the stopper and communicates with the air over the mercury in the bottle. The bottle is placed upon the shelf of the Jolly balance. A bicycle pump is used to produce the maximum pressure and the variation of pressure, after each reading, is produced by opening the pinch cock and allowing a little air to escape. The height of the mercury column in A can be varied each time by a few millimeters, if desired.

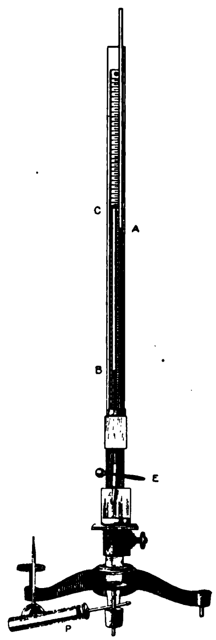

FIG. 7.

The tube through which the air passes is a capillary tube, the others are of the ordinary size used for chemical purposes. The tube B is closed by inserting a glass plug and covering it with cement. This has proved satisfactory. In some cases we have fitted the tube with a plug and fused it in.

A member: Do you fix the plug in place before you put in the mercury?

Mr. Williams: Yes; there is no objection to doing so, as the amount of air in the tube is easily adjusted afterward by holding the tube in a horizontal position.

This apparatus affords an opportunity for a little more accurate work than can be done with the apparatus usually used in the schools. It eliminates all error due to the stretching of rubber tubes. The mercury comes in contact with nothing but glass after the amount of the air in B has once been adjusted. The apparatus is inexpensive, light, portable and is easily manipulated.

I have treated the data as explained by Mr. Chute. The difference, B–C, is taken as the volume and the pressure is found by adding the barometric reading to the difference, B–A. This difference may become negative, thus giving pressures less than atmospheric pressures.

The last column consists of the products of the volume by the corresponding pressures, and shows an extreme variation of a trifle over one-half of one per cent.

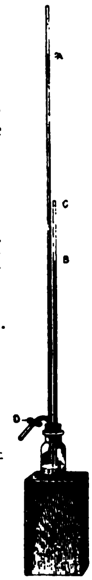

FIG. 8.

C = 18.00. Barometric reading 74.20 c. m.

B	A	B–A	P	V	PV
30.43	13.40	17.03	91.23	12.43	1134
31.00	17.90	13.10	87.30	13.00	1135
31.55	21.90	9.65	83.85	13.55	1136
32.10	25.80	6.30	80.50	14.10	1135
32.63	29.15	3.48	77.68	14.63	1136
33.34	33.45	-0.11	74.09	15.34	1136
34.02	37.11	3.09	71.11	16.02	1139
34.73	40.90	-6.17	68.03	16.73	1138
35.39	44.00	-8.64	65.59	17.39	1141
35.98	46.70	-10.72	63.48	17.98	1141
36.70	49.90	-13.20	61.00	18.70	1141

Mr. Chute: How do you account for the gradual increase of the products?

Mr. Williams: It will be noticed that the products show a gradual increase with increasing volume. There are four ways that I have thought of to account for this peculiarity, and each, upon investigation, has proved unsatisfactory, and I do not think of another.

1st. Suppose the tubes were not of the same bore throughout, but were larger at the top than at the bottom. This would seem to account for it. I tried it with the tube the other end up, this ought to give products that decrease with increasing volumes, but it did not.

2d. Another supposition was that as the work proceeds the heat from the body will warm the air in the tube thus causing it to expand. To test this, I began with maximum volume and minimum pressure, still the products were larger with the larger volume.

Again, if there were minute air bubbles in the mercury clinging to the sides of the tube, they would be liberated as the mercury column falls, and thus the volume would be increased. If, however, the operation is begun with low pressure and the pressure gradually increased, any error due to this ought to be eliminated.

Finally, I began to wonder if moisture in the air could cause the variation in products, so I filled the tube with dry air, but it made no difference. This same variation occurs with the other forms of apparatus.

Prof. Carhart: A constant error in reading the volume would account for it, would it not?

Mr. Williams: I think not, Professor, because if the volume were read always too large, the products would decrease and not increase with increasing volume, and, considering the tendency of capillary action, I can see no reason for supposing that the readings of the volumes are too small.

Dr. Guthe: If he finds out what the reason is, it will explain my curve.

The Chairman: Has any one else, in experimenting with Boyle's Law, noticed this constant increase in the products as the volume grows larger?

(Several said that they had noticed it.)

Prof. Carhart: I am not yet satisfied but that if you read the volume too small it will not produce the error.

The Chairman: Your suggestion then would be that the error is due to the meniscus. Have you experimented with tubes of different dimensions?

Mr. Williams: No, Sir; but I have experimented to see if a small constant error would make any difference, and I find that if the readings are taken at the top of the meniscus, the variation in products is practically the same as when taken at the bottom. I find that no slight error will account for the peculiarity of the results.

Dr. Guthe: Mr. Miller, do you remember how large a volume must be added to allow for the meniscus?

Mr. Miller: Four-tenths of a millimeter.

Dr. Guthe: So if you read at the top, your readings are too small by four-tenths of a millimeter.

NOTE.—This apparatus has since been made in a smaller and lighter form for use in finding the coefficient of expansion of air. The tube through which the air passes as it is pumped into the bottle, is made a little longer than the tube B. The apparatus is put into cold water that is deep enough to cover the tube B. By varying the air pressure in the bottle, the mercury in the two tubes, A and B, is brought to the same level, then the volume is measured and the temperature taken. The process is repeated with water at a temperature about 20° higher. The coefficient a is calculated by the formula

$$a = \frac{V' - V}{V(t' - t)}.$$

AN IMPROVED FORM OF ATWOOD'S MACHINE.

BY MR. W. H. HAWKES, ANN ARBOR.

One of the forty problems recommended by the Physical Conference was the study of the Laws of Accelerated Motion. In general the high school laboratories will be found destitute of any apparatus for verifying these laws. In some cases this is doubtless due to the expense of such apparatus, but more often to the difficulty in obtaining data of sufficient accuracy to be of any value. The inclined plane, the time-honored device employed in the study of these laws, is at best capable of little more than a qualitative demonstration of their truth, while the nature of the problem demands quantitative treatment, and if the results obtained are not reasonably accurate they do not

' the time and effort spent in securing them. The use of the inclined : involves the errors arising from the observer's estimate of the coinci- ; of two dissimilar sense perceptions; either the click of the clock and of all against a ruler held across the plane, or the position of the moving it the instant the click of the clock is heard. In either case the demand is reat upon the untrained perceptions of the high school student, and the s of observation render the results of little value.

The old form of Atwood's machine involves y all the sources of error manifested by the in- l plane, so that only approximate and often d results are obtained from its use, while the amount of time consumed in securing sufficient is an almost fatal objection to its employment boratory classes enrolling many students. For reasons this useful and instructive experiment many laboratories been supplanted by prob- of lower importance, because they require less nental skill and furnish more accurate results. s in contending with these difficulties that we on the device I have to present to the Confer- to-day. It has been in use in the physical atory in the Ann Arbor high school for the past ears with very gratifying results.

FIG. 9.

The machine, Fig. 9, consists essentially of a ilum, a marking device controlled by it, and a hung upon delicate bearings carrying upon its belt of tissue paper tape upon which the record be made, and to which are attached the counter- l masses and the overweight. The pendulum t adjusted so that the needle point at its lower tands, when at rest, exactly in the center of the iry globule through which it passes in closing the ic circuit controlling the recorder. After the ler has been adjusted, a switch throws in the y on this circuit, and at the first passage of the ilum through its lowest point, the wheel is iatically released and the first mark is made upon cord tape. As the motion continues, the spaces l over by the moving system of weights is re- d by the marker, and when the falling weight early reached its lowest point, the operator a second electric circuit which energizes a stopping simultaneously the wheel and the ling pen.

'he completed record is easily detached from the machine for measure- or it may be measured as it hangs upon the machine, by means of a ated column and a sliding pointer reaching out in front of the marked By this means the measurements may be read from the tape direcuy. le I is shown the results of the measurements of ten different tapes.

TABLE I.

RESULTS AS TAKEN FROM MACHINE.

I	II	III	IV	V	VI	
Trials.	S End of 1st Interval.	S Second Interval.	S Third Interval.	S Fourth Interval.	S Fifth Interval.	Si
1	3.6	14.3	32.3	57.7	90.1	
2	3.6	14.4	32.4	57.7	90.3	
3	3.5	14.1	31.6	56.4	87.9	
4	3.4	14.0	31.8	56 6	88.9	
5	3.6	14 2	32.2	57.2	89.5	
6	3 5	14.4	32 3	57.6	89.8	
7	3.8	14.4	32.2	57.2	89.3	
8	3.7	14.3	32.3	57.3	89.5	
9	3.6	14.5	32 6	57 9	90.3	
10	3 5	14.0	31.6	56.4	88.2	
Mean	3.58	14.26	32.13	57.2	89.38	

Each tape shows the spaces passed over during six consecutive se(indicated by the values set opposite in the successive columns.

In table II is shown a summary of the data furnished by the te together with the formula applicable in each case. The quantities

TABLE II.

A	B	C	D	E	F	G	H
Time Interval.	Total Dist.	Dist. each Second.	Vel. at end of each Sec.	Acceleration.	Ratio of S.	Ratio of S′.	Ratio of Vel.
Sec.	S	S′	V	A			
1	3.58	3 58	7.16	7.16	1.0 $(1)^2$	1.0 ... 1	1. ...
2	14.26	10.68	14 26	7.13	3.98 $(2)^2$	2.97 ... 3	2. ...
3	32.13	17.87	21.42	7.14	8.97 $(3)^2$	4.99 ... 5	3.02 ...
4	57.[illegible]0	25.07	2[illegible].60	7.15	15.97 $(4)^2$	6.99 ... 7	4.02 ...
5	89.38	32 18	35.770	7.154	24.96 $(5)^2$	8.98 ... 9	5.03 ...
6	128.67	39 29	42.888	7.148	35.94 $(6)^2$	10.97 ... 11	6.01 ...
	$S = \frac{1}{2} a \tau^2$	$S' = \frac{1}{2} a (2\tau - 1)$	$V = a\tau$		$S \propto \tau^2$	$S' \propto (2\tau - 1)$	$V \propto \tau$

are measured from the record directly, the values in the remaining are calculated from these by application of the formulæ for ac(motion.

A glance at table II gives us an idea of the uniform accuracy of th and is a sufficient comment upon the value of the experiment in the this difficult problem. In actual laboratory practice, a set of thirt may be accomodated with ten tapes each in an hour and a half. Bef begin work, the various parts of the machine, together with the pre necessary to its successful manipulation, are carefully explained to tl class. The laws and formulae of accelerated motion are also reviewed that the full meaning of the distances to be measured may be appreci the pupil. On beginning work, a tape is given to each student ready to measure; he measures it and passes it on to the next pupil; by th

measured a new record is run off by the machine so that a new record is stantly passing through the hands of each pupil. From the data thus ured, the remainder of the problem is easily solved.

You will notice a small variation in the length of the distance, laid off ing the first time interval. The cause is perhaps due to the mercury con- as the mercury oxidizes slightly as the electric spark takes place there.

Prof. Carhart: Are you sure you start the pendulum swinging in the e direction each time?

Speaker: It makes no difference from which side you start it swinging as supposed to be swinging when the circuit is closed, hence it may strike on er side first; but if the pendulum has been adjusted to hang exactly in the er of the mercury globule it will make no difference.

I may add, in conclusion, that in an experiment to test the accuracy of machine in finding the value of g, the value of 978.98 was found by sub- ting in the formula

$$g = \left(\frac{W + W' + w}{w\ T}\right)a$$

hich

W = mass of counterpoise weights, tapes and clamps.
W^1 = The wheel constant for that particular machine.
w = The overweight.
T = Time of one vibration of pendulum.
a = The observed acceleration.

APPARATUS FOR COEFFICIENT OF EXPANSION OF SOLIDS.

BY DR. KARL E. GUTHE, ANN ARBOR.

Two methods are generally used for measuring the coefficient of expan- of solids; one in which the lengthening of a rod is measured by me ns of crometer screw, and one in which the rod actuates a lever or a system of rs, thus magnifying the amount by which the body under experiment expands. instrument before you (Fig. 10) is a modification of the latter class. The figure represents the part with the lever arrangement: T is a brass tube containing water and a thermometer for reading its temperature. It is closed at both ends by thin rubber stoppers S through which the ends of the rod R pass. One of these ends is pressed firmly

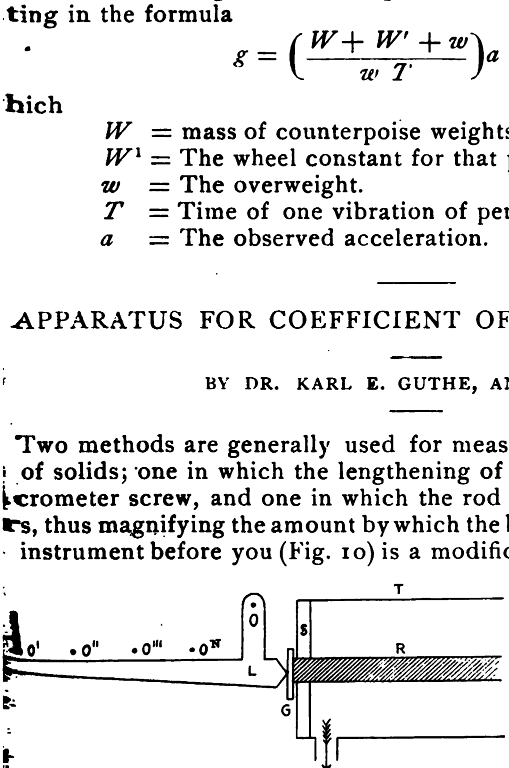

FIG. 10.

nst a fixed object, in our case an adjustable brass screw, connected firmly the wooden support of the instrument. The other, movable end, depicted e figure, is separated from the main lever L, by a thin piece of glass G, h is held in position by the pressure of the lever itself. The lever rotates t the fixed point O as a center; M is a little mirror turning about the point d actuated from the lever L, by means of a small needle F resting in a ve cut in its upper surface.

Suppose the rod under investigation lengthens by an amount equal to a

cms. Let l_1 be the length of the short vertical arm of the lever (1.5 cms.) and l_2 the length of its horizontal part up to the point F, (8 cms). The lever will turn through an angle α, such that

$$a = \alpha\, l_1 \quad \text{and}$$
$$b = \alpha\, l_2$$

where b is the distance through which F moves upwards.

The mirror will turn through an angle θ, such that

$$b = \theta\, \rho$$

where ρ is the distance O^1 F, (1 cm.).

Eliminating α and b from the above equations, we obtain

$$\theta = \frac{l_2}{l_1} \frac{a}{\rho}.$$

Since $\frac{l_2}{l_1} \frac{1}{\rho}$ is a constant of the instrument, we can write $\theta = K\, a$, and determine the constant of the instrument by putting glasses of known thickness between the end of the bar and the lever and observing the resulting rotation of the mirror.

The sensitiveness is further increased by observing the motion of the mirror by means of a telescope and vertical scale. If A be the distance of the scale from the mirror and d the observed deflection, expressed in the same units, we can easily determine θ from the equation

$$\tan 2\,\theta = \frac{d}{A}.$$

The special features of this instrument, distinguishing it from others of the same class are: 1) That the system of levers is fixed to a wooden block which can be moved parallel to the axis of the rod, *thus allowing an easy adjustment of the long beam to the proper level*, and 2) that it is possible to put the mirror at different points O′, O″, O‴, O⁗, i. e. in fixed grooves of the wooden block, thus changing l_2 and *varying the sensitiveness of the instrument*, so that bars with widely varying coefficients of expansion may be investigated. The instrument is easily constructed and its cost will not exceed that of the apparatus commonly in use for this experiment.

The following table contains some of the results obtained by students in the laboratory.

(1) Steel rod of length 69.25 cms.

Mirror at O‴. K = .00264.

Temp.	A	d	$2\,\theta$	Coefficient.
1°		0		
10.7°		7.4	2° 52′	.0000101
33.1°	148	25.7	9° 51′	.0000113
44.7°		34.8	13° 14′	.0000113
99.0°		88.8	30° 58′	.0000119

(2) Glass rod of length 69.5 cms.

Mirror at O'. K = .001335.

6°	144	0		
10.8°		10.6	4° 13'	.0000075
30.4°		31.5	12° 20'	.00000778
48.0°		51.5	19° 41'	.00000788

As you see we are able to show the increase of the coefficient of expansion with increasing temperature.

A few hints as to the practical work should be added. The water to be sent through the brass tube is contained in an ordinary pail, stirred vigorously before the beginning of the experiment and then siphoned through the instrument by means of rubber tubes. In a very short time the temperature of the rod becomes constant and the reading of the scale is taken. The insertion of the thin glass pieces G at both ends of the rod is of greatest importance, since by it a small error due to the conduction of heat from the rod to other metallic parts of the instrument is avoided. The sensitiveness is moreover so large that it is possible to confine the temperature changes within relatively small limits.

At 5:00 p. m. the Chairman announced that the conference would adjourn, to reconvene Saturday, April 1st, at 1:30 p. m.

SESSION OF SATURDAY AFTERNOON.

The meeting convened at 1:30 p. m. upon call of the chairman. The report of the committee on nominations being called for, Mr. Chute reported as follows: Mr. Chairman: The committee had a session yesterday afternoon and unanimously agreed upon the following nominations:

For Chairman of the Conference for the ensuing year, Professor John O. Reed of the University of Michigan. For Secretary, Mr. F. A. Osborn of Olivet College. Upon motion the report of the committtee was adopted and the gentlemen declared elected.

The preliminary business being completed the Chairman announced the next paper upon the program.

A MODIFICATION OF ADAMS' METHOD FOR PRESSURE IN FLUIDS.

BY MR. R. B. DEAN, PONTIAC.

In the work in the laboratory during the past year we found difficulty in obtaining satisfactory results in the first problems under Mechanics of Fluids, as described in Adams' Manual, pages 55–59. The method there proposed is briefly this: A cylindrical glass jar about 8 cm. in diameter and 40 cm. deep, having a paper scale pasted vertically down its side, is filled with water. Three glass tubes, each about 75 cm. long and 4 mm. inside diameter, bent so as to receive downward, upward and lateral pressure respectively, are filled with mercury at the bend to a depth of about 2 cm. in each case. An adjustable clamp for holding the tubes vertically in the water, completes the apparatus.

Each tube is lowered in turn into the jar, until its mouth is at least 15 cm. below the surface of the water; proceeding from that depth downward readings upon the surface of the water, and the height of the mercury in each one of the bent tubes are made for a series of positions of the tube. From the data thus obtained the laws of liquid pressure are to be deduced.

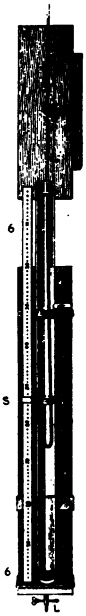

FIG. 11

Two sources of error seem to preclude satisfactory results. It being necessary to begin the readings at least 15 cm. below the surface of the water it will be seen at once that the range over which measurements may be taken is but 25 cm.; too short for satisfactory work. Again, with a jar of 8 cm. diameter the errors arising from the readings themselves seem likely to be unduly large. It was in the effort to obviate these two difficulties that the present arrangement was devised.

A tube of 4 cm. internal diameter and 100 cm. long, open at both ends, was fastened in an upright position against the wall, as shown in Fig 11. To the lower end was fitted a rubber stopper penetrated by a glass tube, to which was attached a bit of rubber tubing clamped by the pinchcock L, for adjusting the depth of the liquid in the tube. For a scale a common meter stick was attached to the support about one-fourth inch from the tube, as shown in the figure. A bent clamp, S, fitting the tube snugly and moving with some friction extends out over the scale at right angles to the tube and serves as a reading index for the scale. The bent tubes are supported in position by a small clamp, as shown in the figure. Readings are made by adjusting the bent mercury tube to a certain depth greater than 15 cm. below the surface, and then slipping the clamp, S, down until the upper edge just coincides with the surface to be located; the scale reading is then taken. The results obtained in this way are much more accurate than those made by the previous method, the error being reduced fully one-half. Although there are still some variations which it would seem desirable to remove, yet as we take the elevation of the mercury *per unit depth* we find that we get, by taking the mean of the three elevations, corresponding to lateral, upward and downward pressure, an average error of about one-half of one per cent, and we feel that this is an error which high school pupils are liable to make in any experiment.

A DEVICE FOR MEASURING UPWARD PRESSURE IN FLUIDS.

BY MR. N. N. CHUTE, ANN ARBOR.

The apparatus consists of a tall glass jar, filled with water, and an aluminium tube, about 1.5 cm. diameter and 60 cms. long, with one end closed water tight by a lead plug of such weight as to cause the tube to float vertically in water. For ease in measuring the portion submerged, the tube is graduated as shown in Fig. 12. To show that the upward pressure on a surface is proportional to the distance of that surface below that of the liquid, weigh the tube, then float it in water and note the amount submerged. Now drop known weights into the tube and note the amount of submergence each time. In this way, a series of upward pressures and corresponding depths will be obtained, which, when plotted on cross-section paper in the usual way, gives a straight line, showing the truth of the proposition.

To show that the upward pressure is proportiomal to the area of the surface pressed upon, a second tube, of larger cross sectional area, will be needed, By calipering each tube, the areas of the surfaces pressed upon can be found, and compared with the weights of the tubes when floating submerged to the same depths.

The apparatus c n be cheapened by substituting paper tubes thoroughly coated with paraffin for the metal one, and large shot may be used for weights.

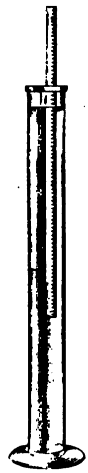

FIG. 12.

QUANTITATIVE EXPERIMENTS WITH THE SIPHON.

BY MR. N. B. SLOAN, FLINT.

The experiment I have to show is simple indeed and perhaps its simplicity may constitute its chief recommendation to your consideration. We have all doubtless had some experience in attempting to convince our students of the truth of the law of the siphon. What I have to show is a method for showing this law which has proven very simple and satisfactory.

I was one day using a siphon to transfer some salt solution from over some mercury and happened to dip the siphon arm under the heavy liquid. Of course the solution ceased flowing and the mercury rose in the tube to a little distance. It occurred to me that this might be made a means of testing the law. I tried a few times, at first lengthening the arms by rubber tubing or by using siphons of different length. Finally, at the suggestion of one of my students, Mr. Howard Keeney, we added the rubber tubing as shown in the figure. Thus the apparatus took form.

The apparatus, Fig. 13, needs but few words of explanation. It consists simply of a glass tumbler A containing some mercury, supported by a

block. A glass tube is bent in the form of a siphon to which is attached a rubber tube leading down and up again to a straight piece of glass tubing B, attached in front of a scale and arranged to slide up and down the scale. Above the mercury in the tumbler is placed some water, merely as a convenience in filling the siphon. Behind the siphon arm is an adjustable scale for reading the elevation of the mercury as it rises in the tube. The long scale is also adjustable, so that the water in the straight glass tube, the top of the scale and the water in the dish, may be placed at the same level. The siphon is filled with water, the end dipped under the mercury, the scales adjusted, and we are ready for the experiment.

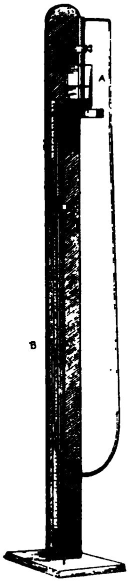

FIG. 13.

The first thing to be noticed is that the mercury in the siphon tube stands below that in the dish. Here is capillary depression and the student cannot well fail to see that it requires the weight of a certain measurable quantity of water in the long arm of the siphon to overcome this depression. To correct for this the tube must be moved down the scale 2.5 cms. Here, then, is a force, real and actual, which must be taken into account in our calculations, and it occurs to me that every time we bring the student face to face with the fact that these forces are realities, not theories, we are teaching the lesson which the physical laboratory more than any other agency is intended to enforce.

The rest of the experiment is simplicity itself. Slide the tube down the scale until the water level reads 12.5 cm. or 10 cm. below the level after being adjusted for the capillary depression. The mercury goes up in the siphon tube to 8 mm. Now 22.5 cm. or 20 cm. below the first reading, the mercury goes up to 16 mm.; 30 cm. and the mercury reads 24 and so on for the following values:

Water Level	40	Mercury	32
" "	50	"	40
" "	60	"	48
" "	70	"	56
" "	80	"	64

Every increase of 10 cm. in the length of the long arm causes a change of 8 mm. in the mercury level.

After getting the data, having made several trials, using each time a different length of arm let the student plot the results, using the length of arm as one variable and the height of mercury as the other. The result is a straight line, as perfect and suggestive as you please, with the measurement at the beginning, indicating that the capillary depression for this tube is 25 mm. Now let the student find the diameter of the tube, calculate the weight of mercury for the different lengths and he has a measure of the actual pull exerted by the siphon.

As a subsidiary experiment suppose we find the volume of water used in any of our readings. Call the density of the water 1; then this volume in cc. will also be the weight of mercury in grammes. We have the volume of mercury from a previous calculation. Divide this weight by volume and we have the density of the mercury.

A LABORATORY METHOD FOR THE INCLINED PLANE.

MR. H. M. RANDALL, SAGINAW, E. S.

The inclined plane consists of a board about 125 cms. long, and from 20 to 30 cms. wide, furnished with an adjustable prop, by means of which several different elevations ranging from 20 to 40 degrees from the horizontal may be obtained. The board should be smooth and free from warp. Such an inclined plane is described in Adams' Laboratory Manual.

The car used is of iron with pivoted brass wheels. It should run with little friction and be easily adjusted to run directly forward. Such a car is furnished by the Knott Apparatus Co. and weighs about 500 gms. The draw scale used in measuring the effort required to draw the car up the incline should work without friction. In practice, since the car used can not carry much of a load, about 100 to 200 gms., light Franklin balances have been used. The capacity of these is 200 gms. and they are graduated in 10 gram divisions. Whether heavier loads and scales of greater capacity would produce greater accuracy I cannot say.

The method by which this problem is worked is practically that given in Chute's Laboratory Manual. The car, attached to the hook of the draw scale by a string six or eight inches long, is drawn by hand toward the top of the incline, the latter having been adjusted at a suitable elevation. Care has to be taken to hold the draw scale in the hand in such a way that the string is kept parallel to the incline. Also the motions up and down the plane should be uniform. While the car is thus moving the readings on the draw scale are taken, and the average of several trials up and down represents the effort. The weight of the car and its load, the length and height of the inclined plane are obtained, and the accuracy of the measurements tested by the law that "the weight divided by the effort equals the length divided by the height, when the effort is applied parallel to the length of the plane."

There are numerous sources of error in this problem. Until, however, the car can be drawn up and down with approximately uniform velocity, the string kept parallel to the incline, and the scale read with some degree of accuracy while in motion, all other sources of error may be neglected as these are the chief ones, provided the apparatus is in order. This problem, worked in the manner indicated above, demands that the pupil in his preliminary tests acquire a considerable degree of skill in handling and reading his apparatus. The results of the majority of the pupils show differences of from two to three per cent., though some who uniformly do good work get as near as one per cent. This shows that the degree of skill required is rather greater than can be acquired in the process of one experiment.

Another method of moving the car and measuring the effort is given in Adams' Laboratory Manual. According to this method the car is drawn up the incline by a string passing over a pulley located in the upper end of the board and carrying a scale pan in which weights are placed. If the pulley is properly placed the effort will always be parallel to the incline and the proper weights can be placed in the pan to give the car uniform motion on the plane, both up and down. This latter method is apparently the more desirable as the only demand made upon the pupil after properly setting up the apparatus is to determine when the car moves with uniform motion after it has once been started on its course either up or down.

However, the friction of the pulley is a very important factor, and with :e pulleys used, when the wheels were sometimes free from the enclosing des and sometimes rubbing against them, consecutive trials with the same ·ad and elevation would give efforts which would vary from each other by om 50 to 100 gms. This variation seemed to be too large a fraction of the ›tal effort and led to the adoption of the first method, where the scale read-.gs could usually be taken to within 10 gms. It is possible that another .boratory fitted with different draw scales and pulleys might find that the best !sults could be obtained by the second method.

ON THE LEGAL FORM OF THE STANDARD CELL.

BY PROFESSOR H. S. CARHART, ANN ARBOR.

Many of you may not be aware that there is a legal form or stańdard of ectromotive force in the United States, made legal by an act of Congress . 1894, the bill having been signed by President Cleveland.

At the risk of seeming to introduce myself too much, if you will pardon , I should like to give a short account of how this form of cell came to be ie legal standard in this country. At the time of the International Congress : electricians at Chicago, in 1892, a committee was appointed by a special ›dy, the "Chamber of Delegates," consisting of accredited representatives om ten different nations, each sending delegates running from five, as in the ıse of the United States, Great Britain and Germany, down to one. This ›mmittee was entrusted with the duty of framing specifications for setting up .e standard Clark cell. The chairman of that committee was the late Profes-›r von Helmholtz of Berlin; the other two members were Professor Ayrton of ondon and myself. You will remember that Professor von Helmholtz suffered ı injury in going back to Germany and died a year later, but before he died ·had a long communication from him on this subject. A number of letters ıssed between Professor Ayrton and myself relative to the standard cell. 'e did not come to any agreement. Perhaps if the incident had occurred at .e present time, when England and America are more *en rapport*, we should have ıd less difficulty in reaching an agreement. Professor von Helmholtz and I greed on the form proposed by Dr. Kahle, which is a modification of Lord ayleigh's. To my mind there were many reasons why that form was the ›st, and better than the tube form which the English preferred. They per-sted in making the standard in the form of a tube in which both wires run ›wn through small glass tubes to the electrodes. A small rod of zinc dips .to the zinc sulphate solution with crystals, it may be, at the lower end and ısaturated solution at the upper. I pointed out the disadvantages of that ›rm, but Professor Ayrton did not appear to recognize them. At the meeting : the British Association in Toronto, however, he admitted the superiority : the form which the United States has adopted.

After the death of Professor Helmholtz and the consequent failure of the .ternational committee to report, the matter was taken up by Professor :endenhall, then Superintendent of the Coast Survey, and through his .fluence a bill was introduced into Congress to legalize all the electrical ıits of measurement. For the specification of the Clark cell Professor :endenhall conceived that it afforded a good opportunity to bring the

National Academy of Sciences to the attention of Congress. Since co gress could not leave the matter to an international committee over which had no control, it was agreed to refer it to the National Academy. Tl President of the Academy made Professor Rowland chairman of the Acaden committee, and at his request I sent him a draft of a specification for tl construction of a normal Clark cell. He had proposed to adopt the English spe ification, but after I pointed out its objections, he admitted that they we well taken and accepted the corrections I made. The specification drawn ı by the committee, and embodying all my suggestions, you may now find the reports of Congress; you may also find it in Electrical Measurements l Professor Patterson and myself.

I have brought two cells here put up according to the legal specification. These are the particular ones Dr. Guthe and I intend to investigate soon. Professor Patterson and Dr. Guthe have redetermined the electro-chemical equivalent of silver, and their revised value, which exceeds the old one by one-tenth of one per cent., explains certain discrepancies. As the work was very carefully done, we believe it better than the old one. One result is that the E. M. F. of the Clark cell is reduced to 1.4327 volts at 15° C.

FIG. 14.

The platinum wires should be sealed into the legs of the glass cell with very soft lead glass. Unless this is done, the glass is almost sure to crack on the amalgam side. In one leg we have the mercury covered with mercurous sulphate and zinc sulphate crystals; in the other the zinc amalgam made by heating nine parts by weight of mercury with one part of pure zinc. the temperature of boiling water this amalgam is fluid. It can be put into t glass cell through a very small funnel tube when the cell is immersed in a h water bath. The amalgam must also be well covered with crystals of t sulphate. The cell is mounted so as to stand on four brass legs wh removed from the case for the purpose of immersion in a bath; when not use it is put into the case to keep it from the light. We use a bath of petrolei or paraffin oil so that we may know the exact temperature at which a co parison is made.

One reason why this form is preferred is as follows: The temperatı coefficient of the Clark cell is large, and half of it is due to the changes density of the solution as the zinc sulphate crystals dissolve or recrystalli: This process is a slow one and the E. M. F. of the cell lags in consequer behind the temperature changes. If the temperature is rising, the E. M. is too high and if it is falling, it is too low. But in this legal form, in whi the crystals of zinc sulphate are in contact with the zinc amalgam on one s and with the mercury on the other, this time lag is eliminated, because two electrodes are always in contact with a saturated solution of the z salt. Professor Ayrton himself has determined that we get no apprecia lag with this legal form, while the English form shows a very considera lag

As a legal standard we have, therefore, the form which I show you he conforming exactly to the requirements of the United States law.

A DEVICE FOR SHOWING POLARIZATION IN A SIMPLE VOLTAIC CELL.

BY MR. H. N. CHUTE, ANN ARBOR.

This device, taken from Ayrton's Electricity, is for exhibiting to a class the phenomenon of polarization of the simple voltaic cell. A good galvanometer is necessary, one whose movements can be seen by the class. I use a d'Arsonval galvanometer, provided with a concave mirror, which reflects an image of the flame of a lamp on the screen, the room being darkened.

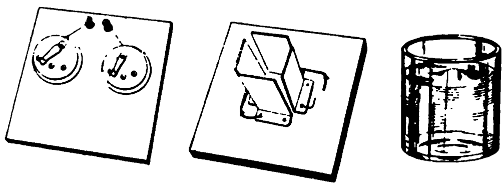

FIG. 15.

To construct the apparatus, Fig. 15, fasten two zinc strips and two copper strips to a piece of board about 15 cm. square, the strips being arranged about the sides of a square about 4 cm. on a side. Connect these strips through the board to the two-point switches fastened to the opposite side. It is advisable to make the connections in such a way that the switch can be used to connect a zinc and copper strip. Two binding posts will be needed and these connected with the switches. It will now be possible to connect either the two zincs, the two coppers, or a zinc and a copper to the galvanometer. A common battery-jar or large tumbler containing dilute sulphuric acid completes the apparatus.

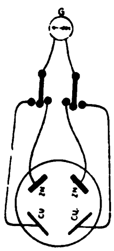

FIG. 16.

To operate the apparatus, connect the two zincs, which we will call Z and Z′, to the galvanometer, by turning the switches to the inner points, Fig. 14. Probably a small deflection will be obtained. Now connect the two coppers, C and C′; the result will be about as with the zincs, only less marked. In the next place, set one of the switches so as to set in circuit a pair of battery elements, as Z and C, and let it remain for several minutes. If the two coppers, C and C′, be now connected to the galvanometer, a large deflection of the galvanometer will be obtained, and in a direction showing that a current is flowing from C′ to C through the external circuit.

A M mber: Could the apparatus be used with but one zinc?

Mr. Chute: Yes; but you could not show that two zincs will give a small current.

A Member: Do you amalgamate the zincs?

Mr. Chute: The ones that I use have been amalgamated.

The Chairman: It seems to me that the device is an exceedingly interesting and useful one. The student is told in the text book that there is a back electromotive force, and he accepts that as he does a great many other things, as established from the foundation of the world.

Prof. Carhart: What you really have in a simple voltaic cell, after it has been in action for a time is a gas battery.

Mr. Gorton: May I ask how sensitive a galvanometer is required to show the difference between the two zincs?

Mr. Chute: I use one of the d'Arsonval type, the helix being of No. 40 wire and 100 ohms resistance.

Mr. Adams: I find that the simple testing galvanometer used in our laboratory will give a deflection of 10 degrees between two zincs.

A NEW DAMPER FOR A GALVANOMETER.

BY MR. R. B. DEAN, PONTIAC.

I think there are some teachers who have met with difficulty in the use of the d'Arsonval galvanometer in the high school. I have heard some say that they felt it could not be used by the average high school student. One disadvantage is that this galvanometer mirror vibrates so long that the average high school student gets discouraged before he can read the scale. This may be overcome by short circuiting, but often this does not bring the mirror down so that there is no vibration. As a general thing high school pupils do not get this very satisfactorily. We wished to use this galvanometer and at the suggestion of our teacher in chemistry we have made a form of damper that has been quite satisfactory in the work. The apparatus is here and you will have an opportunity to learn how it works by reading the scale through the telescope. We have it mounted here as we commonly use it. The damper consists of a small trough made of brass or copper as you see, placed above the magnet upon the side of the galvanometer; then at the top of the mirror we solder on a short piece of wire, and at the right end of this wire, and just dipping down into the trough, we have a paddle which is so placed that it extends into some liquid in the trough. Of course any liquid may be used. One could use water, but that evaporates. We use an oil. We first used machine oil but it did not work well. I have here some kerosene oil. The arrangement is so simple that I need not say anything further in regard to it unless some one has a question to ask. I might say that the whole arrangement as you see it here is one that we have made up for use in the laboratory and one of the difficulties which we all encounter is to get a firm support for the galvanometer. In order to meet this difficulty we have a table a little higher than this one, strapped to a stone wall, thereby giving us a good solid support. It appears at once that there may be a very little jar which comes from any movement of the telescope. In fact we found after we had strapped the table to the wall, there still was a little movement in the galvanometer and in order to overcome that we plugged the stone wall just above the table and fastened pieces of wood upon the wall. Upon these pieces we placed some brackets and above the table on these brackets a two by four support. Upon this support we have placed our galvanometer, which is now above and free from the table, the support being fastened to the wall. Thus we overcame the difficulties we met, first the one of damping the galvanometer, and secondly that of getting a solid support for it.

The Chairman: It occurred to me that a possible objection might be that the damper is only on one side; it would work with greater freedom if it had two little dampers arranged symmetrically as to the mirror. How many of the workers here use the telescope and scale in measuring deflection? [Four responded].

Mr. Randall: You are very apt to have to make the adjustment yourself unless the students learn how.

The Chairman: You find they are slow to understand they must do it themselves?

Mr. Adams: The big sleeves used to play their part in knocking the telescope out of line.

Professor Carhart: Do you mount this apparatus yourself and adjust it?

Mr. Dean: Yes, sir, I begin by putting it in adjustment and have it in shape to begin work at once.

Professor Carhart: Every time?

Mr. Dean: I do when we first begin work, but after the pupils have worked for some time I feel it is well enough to move the telescope out of line and let them adjust it. But if we ask them to set it up without having any experience, it is asking too much, and they will become discouraged before beginning their task.

ON THE TESTING OF ARCHIMEDES' PRINCIPLE.

MR. C. F. ADAMS, DETROIT.

The exercise for testing the principle of Archimedes in our laboratory is preceded by two others earlier in the term which are preliminary to it; one in which the pupil is given a small metal cylinder to determine its density by weighing it and by finding its volume from measurements of its dimensions taken with the vernier caliper or the micrometer screw; the other, an exercise for determining the density of water by weighing a quantity of water whose volume has been measured by a burette.

The only operation now necessary for this experiment is to find the weight of the cylinder used in the first exercise while it is immersed in water. Its weight in air and its volume can be taken from the data of the previous exercise.

The following data taken from a pupil's note-book will illustrate this experiment:

Weight of cylinder in air	22.89 g.
Weight of cylinder in water	20.20
Loss of weight in water	2.69
Volume of cylinder in cc. (measured)	2.67

The pupil is now asked what volume is displaced by the cylinder, the answer of course being its own volume. This quantity is given in the table.

The pupil is then asked, What weight of water is displaced by the cylinder? Having previously determined the density of water in grams per cubic centimeter and knowing the volume displaced he can at once see the answer to the question. He is then asked to compare the loss of weight in water with the weight of water displaced. Incidentally in answering the question, how many times denser the cylinder is than water, the pupil may learn the meaning of the term specific gravity.

The error here is perhaps considerable, but this result is about as good as can be expected with the use of the Jolly balance. With a more accurate balance it would perhaps be advisable to take into consideration the effect of temperature on the density of the water.

Mr. Chute: I should suggest that the error is in the weights. I have been using weights similar to those used by Mr. Adams, but lately have substituted more accurate weights. I find that with better weights we get more accurate results.

The Chairman: This work has been done with the Jolly balance? A. Yes.

The Chairman: This will close our work for this Conference, and perhaps I may take this opportunity to say, that personally I am much gratified, first, with the attendance; secondly, with the great interest that has been manifested in this work and finally, and most of all, with the excellent character of the devices presented and the indication it gives of a deep interest throughout the state in the work of teaching physics by laboratory methods.

Conference adjourned.

LIST OF BOOKS

RECOMMENDED FOR A

HIGH SCHOOL PHYSICAL LIBRARY

ANY BOOK IN THIS LIST MAY BE OBTAINED FROM GEORGE WAHR, PUBLISHER AND BOOKSELLER, ANN ARBOR, MICHIGAN, AT THE PRICE NAMED, POST PAID.

N. B.—The double asterisk (**) is prefixed to the title of books that are regarded as indispensable to the teacher of Physics. Books somewhat less essential are indicated by the single asterisk. Every book in the list will be found useful.

PROPERTIES OF MATTER.

**COOKE, J. P., Chemical Physics, *Allyn & Bacon*	$4 50
**FARADAY, MICHAEL, Forces of Nature, *Chatto & Windus*	1 60
**MAXWELL, J. C., Matter and Motion, *D. Van Nostrand Co.*	50
PYNCHON, THOMAS R., Chemical Physics, *D. Van Nostrand Co.*	3 00
*RISTEEN, A. D., Molecules and Molecular Theory, *Ginn & Co.*	2 00
**TAIT, P. G., Properties of Matter, *A. & C. Black*	2 25
*WURTZ, A., The Atomic Theory, *D. Appleton & Co.*	1 50
*TYNDALL, JOHN, Forms of Water, *D. Appleton & Co.*	1 50
TOMLINSON, CHARLES, Experimental Essays, *D. Van Nostrand & Co.*	——

MECHANICS.

*BALL, R. S., Mechanics, *H. Holt & Co.*	$ 60
*BALL, R. S., Experimental Mechanics, *Macmillan Co.*	1 50
**BRIGGS, WM. and BRYAN, G. H., Text-Book of Statics, *University Correspondence College Press*	1 20
GOODEVE, T. M., A Manual of Mechanics, *Longmans, Green & Co.*	80
GOODEVE, T. M., Principles of Mechanics, *Longmans, Green & Co.*	2 00
**GLAZEBROOK, R. T., Mechanics and Hydrostatics, *Cambridge University Press*	2 25
**LODGE, OLIVER J., Elementary Mechanics, *W. & R. Chambers*	1 50
*MACH, E., Science of Mechanics, *Open Court Publishing Co.*	2 50
MAGNUS, PHILIP, Hydrostatics and Pneumatics, *Longmans, Green & Co.*	60
PARKINSON, S., Elementary Treatise on Mechanics, *Macmillan Co.*	2 25
*PERRY, JOHN, Practical Mechanics, *Cassell & Co.*	1 00
PINKERTON, R. H., Dynamics and Hydrostatics, *Blackie & Son*	1 20
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LISTS OF APPARATUS

FOR

PHYSICAL LABORATORY

LIST OF APPARATUS FOR A SMALL HIGH SCHOOL TO BE FURNISHED AT AN APPROXIMATE COST OF $25.00

The following list of experiments and apparatus has been prepared to show that the first cost of a physical laboratory need not be great, and also to serve as a guide to teachers in selecting experiments and apparatus. It assumes that the given school has no apparatus for real work but is desirous of laying the foundation of a strong course in physics. The numbers starred are important but may be omitted the first year. After a start is once made, it is not difficult, with judgment and care, to make an annual outlay of $10 to $20 gradually furnish the school with a complete set of apparatus.

C. Refers to Chute's Laboratory Manual. The numbers to the problems.

A. Refers to Adams' Laboratory Manual. The numbers to the problems.

Unless otherwise stated under the experiment the apparatus can be obtained at the price given, from Eberbach and Son of Ann Arbor.

F. A. Osborn.

MECHANICS.

1.	Use of diagonal scale. C. 10. A. I.	
	2 Scales and dividers	$ 80
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	2 Metre rods	60
3.	Use of protractor. C. 17.	
	2 Bone protractors	30
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*5.	Vernier Caliper. C. 13. A. II.	
	Columbia Vernier Caliper	2 50
6.	Volume of solid by displacement. C. 19.	
	100 c. c. Cylinder graduate and float	1 00
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9.	Curvilinear motion. C. 33.	
	5 lb. iron ball	50
10.	Laws of pendulum. C. 35. A. XIV–XV.	
	Small iron or wooden ball	10
11.	Pressure of atmosphere. C. 41.	
	Barometer tube	30

12. Boyle's law. C. 44. A. XXI.
Tubing as per Fig. 5, page 14 .... 2 25
Frame, home made 1 50
13. Buoyant force. C. 46. A. XXIII.
Iron cylinder 10
Balance 1 25
Weights 100 g. to 1 c. g 1 60
14. Principle of flotation. C. 47.
15. Density of solid heavier than water. C. 48. A. XXIV.
16. Density of solid lighter than water. C. 49. A. XXV.
17. Density of liquid. C. 52. A. XXVII.
Specific gravity bottle 30

HEAT.

18. Test thermometer. C. 58. A. XXIX.
Thermometer 75
Flask 25
19. Coefficient of expansion of liquids. C. 64.
Tube 30
20. Coefficient of expansion of solids. C. 63. A. XXX.
Knott Apparatus 2 25
21. Water equivalent of beaker. C. 69.
Small copper beaker. 350 c.c. 30
22. Specific heat of solid. C. 70. A. XXXII.
23. Specific heat of liquid. C. 71.
24. Latent heat of melting. C. 73. A. XXXIII.
25. Latent heat of vaporization. C. 74. A. XXXIV.
Tube glass ....

MAGNETISM—ELECTRICITY.

26. Law of magnets. C. 75. A. XXXV.
2 Bar magnets, 6 in 60
27. Distribution of magnetism in magnet. C. 79.
Magnetoscope 20
Home made.
28. Magnetic transparency. C. 77.
Needle ....
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Plates of iron, copper, lead, carbon, etc 20
*32. Measurement of resistance by Wheatstone's bridge. C. 90. A. XLIII.
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Daniell battery 90
*33. Resistance of battery. C. 92. A. L.
Battery 75
*34. E. M. F. of battery. C. 99. A. LI.

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35.	Velocity of sound in air. C. 108. A. LVII.	
	Fork 256	1 00
	Tube 1 metre	1 00
36.	Velocity of sound in solids. C. 105. A. LVIII.	
37.	Determine vibration rate of fork. C. 108.	
38.	Law of strings. C. 111. LIV–V.	
	Sonometer	2 50
39.	Images from small apertures. C. 113–114.	
	2 screens	40
40.	Candle power of light. C. 115–116. A. LX.	
41.	Reflection of light. C. 117. A. LXI.	
	Plane mirror, needles	15
42.	Position of object in plane mirror. C. 119. A. LXII.	
43.	Focal length of concave mirror. C. 120–121. A. LXIII.	
	Concave—convex mirror, nickel plated	50
44.	Focal length of convex mirror. C. 122.	
45.	Images in concave and convex mirrors. C. 125.	
46.	Focal length of convex lens. C. 128–129. A. LXIV–VII.	
	Lens and holder	40
47.	Focal length of concave lens. C. 131.	
	Lens—holder	45
48.	Images by lenses. C. 134.	
49.	Index of refraction of glass. C. 127. A. LXXII.	
	Glass prism	35
	Total omitting starred numbers	$24 90

EQUIPMENT FOR A PHYSICAL LABORATORY.

All apparatus in this list can be furnished by Eberbach & Son, of Ann Arbor, Mich., at the price affixed.

N. B.—The numbers refer to Chute's Laboratory Manual published by D. C. Heath & Co., Boston, Mass. The letters, A, B, C, refer to the quality of the apparatus. Grade C is capable of giving good results, is equally durable with the other grades, and well suited to the needs of high school laboratories. Those marked with * comprise the list of forty problems adopted by the Physical Conference of the Michigan Schoolmasters' Club.

PROPERTIES OF MATTER AND MECHANICS.

1. *To measure the distance between two points* (10).
   Apparatus:—Dividers—C–.25, B–.50, A 1.00. Diagonal scale metric—C–.15, A–.50.
2. *To measure the volume of brass in a piece of tubing* (13).
   App.—Steel caliper with vernier—C–2.50, B–3.50, A–8.50. Caliper C and B are 100 mm. and 150 mm. long respectively and read to tenths. Caliper A is 100 mm. long and reads to hundredths.
3. *To measure the diameter of a wire* (14).
   App.—Micrometer caliper, metric–4.50.

4. *To measure a cylindrical vessel and compute its volume* (16).
App.—Caliper, inside and outside, C–.15, B–.25, A–.40; Conical graduate, Eng. and met., 250 cc. C–.90. B–1.15; 500 cc.–C–1.30, B–1.75; Metre.rod, graduated to mm. and one-tenth of an inch—C–.25, B–.30.

5. *To measure the angles of a plane triangle* (17).
App.—Protractor—C–.15, B–1.50, A–11.00.

6. *To measure the volume of an irregular body* (19).
App.—Cylindrical graduate, 100 ccm. C–.80, B–0.95; Erdmann's float—C–.30, B–.40.

7. *To measure the mass of a body* (22 and 23).
App.—Jolly's balance—C–5.00, B–10.00, A–17.00; Weights, met. .001g. to 20g.—C–1.00, B–2.00, A 5.00; Beam balance, sensitive to .01g.–9.00; Balance in case, .001g.—15.00—25.00.

8. *To measure the diameter of a glass tube* (24).
App.—Scale and Dividers of No. 1; Balance and Weights of No. 7; Caliper of No. 3; Dropper-bulb–.05.

*9. *To find the relation between the load and the elongation of a spring.*
App.—Same as in No. 7.

*10. *To verify the principle of composition of forces* (30, 32).
App.—Three spring balances, metric, –$1.80; Protractor of No. 5.

11. *To verify the laws of curvilinear motion* (33).
App.—Spring balance No. 9; Iron ball—4 lbs. –.50.

*12. *To verify the laws of accelerated motion* (34).
App.—Iron ball—C–.10, B–,25, or Hawkes' Atwood Machine. 25.00.

*13. *To verify the laws of the pendulum and compute g* (35).
App.—Lead ball, –.25, Wall bracket with clamp–.50; complete pendulum support to clamp to table –4.00.

*14. *To verify the law of the lever* (36).
App.—Knife-edge –.25, Metre stick of No. 4; Weights of No. 7.

*15. *To verify the law of the inclined plane* (39).
App.—Plank, 1.00; Car, 1.00; draw scale of No. 10.

*16. *To measure the pressure in liquids* (40).
App.—Curved glass tubes –1.00; Dividers of No. 1; Metre-rod of No. 4; Glass cylinder–2.00.

*17. *To verify Boyle's law* (44).
App.—Tube and mercury C–3.75, B–6.00, A–8.00.

*18. *To prove that the rate of flow of a liquid from a siphon is proportional to the difference of length of its arms* (45).
App.—Graduate of No. 4; Siphon—.10.

*19. *To measure the buoyant force* (46).
App.—Caliper No. 2; Balance and weights of No. 7; Brass cylinder, solid–.30.

*20. *To find the density of a solid heavier than water* (48 and 50).
App.—Balance and weights of No. 7.

*21. *To find the density of a solid lighter than water* (49 and 50).
App.—Balance and weights of No. 7.

*22. *To find the density of a liquid* (52 and 55).
App.—Balance and weights of No. 7; Sp. Gr. Bottle, C–.25, B–.85.

HEAT.

*23. *To test the accuracy of the location of the fixed points on a mercurial thermometer* (58).
App.—Chemical thermometer, C–1.00, B–1.50, A–2-50: 4-in. Glass funnel, –.12; Florence flask 32 oz. –.25, Iron stand, 2 rings, –45; Wooden stand, universal, –1.25; Bunsen burner, C–.25, B–.40, A–1.00.

*24. *To find the coefficient of expansion of a metallic rod* (63).
App.– Florence flask of No. 23; Thermometer of No. 23; Rubber tubing, –.10; Galvanometer of No. 39; Battery of No. 41; Expansion app., C–2.50, B–4.00, A–6.00. Iron stand of No. 23; Bunsen burner of No. 23.

To find the coefficient of expansion of a liquid (64).
App.—Thermometer of No. 23; Glass tube with fitted corks, –.75; Pinch cock, C–.20, B–.30; Florence flask of No. 23; Bunsen burner of No. 23.

To find the coefficient of expansion of air (65).
App.—Same as last; Additional glass tube, –.05.

25. *To find the melting point of a solid* (66).
App.—Thermometer of No. 23; Capillary tubes, –05; Iron stand of No, 23; Bunsen burner of No. 23; Glass beaker, ½l.–.18.

To find the boiling-point of a liquid (67).
App.—Wide test-tube with cork, –.08; Thermometer, Burner and Stand of No. 23.

26. *To find the thermal capacity of a beaker* (69).
App.—Beaker, 1l.—C–.20, B–.80; Graduate of No. 4; Thermometer, Burner and Stand of No. 23.

*27. *To find the specific heat of a solid* (70).
App.—Same as No. 26, together with loose coil of metal, –.15, or metallic ball–.25.

To find the specific heat of a liquid (71).
App.—Same as last.

*28. *To find the heat of fusion of water* (73).
App.—Same as No. 26.

* *To find the heat of vaporization of water* (74).
App.—Florence flask No. 23; Delivery-tube, –15; Beaker, Thermometer, Burner, Graduate, Stand of No. 26.

MAGNETISM AND ELECTRICITY.

29. *To locate the poles of a bar magnet* (76).
App.—Bar magnet, 4-in.—.30; Pocket compass, C–.30, B–1.00.

30. *To compare by the vibration method the magnetic transparency of sheets of various substances* (77).
App.—Bar maget of No. 29; Magnetoscope, –1.50; Sheets of various substances, –.50.

31. *To compare the strengths of the poles of a bar magnet* (78).
App.—Bar magnet of No. 29; Carpet-tacks –.05.

*32. *To construct the magnetization curve of a slender magnet* (79).
App.—Magnetoscope of No. 30; Knitting-needle, –.05.

*33. *To map out the magnetic field of a magnet* (80).
App.—Extra bar magnet, –.30; Small horseshoe magnet, –.15; Iron-filings, –.05.

34. *To determine the kind of electrification of a body* (83).
App.—Electroscope—C–.75, B–3.50, A–6.00, Proof-plane, –.15; Glass tube, –.20; Rod of sealing-wax, –.20.

*35. *To study local action in the voltaic cell* (84).
App.—Glass tumbler, –.05; Strips of copper and zinc, –.10.

*36. *To study the action of an electric current on a magnetic needle* (85).
App.—Compass of No. 27; Support for metal strips, –.30; Compass block, –.30; Copper wire, No. 24, insulated, –.05.

*37. *To construct an electromotive series* (86).
App.—Compass, Compass block, Wire, Stand of No. 36; Strips of different metals, –.25.

38. *To study polarization in the votaic cell* (87).
App.—Same as No. 36.

*39. *To measure the electrical resistance of a conductor:—(a) By substitution* (89). *(b) By Wheatstone's bridge* (90).
App.—Daniell's battery, C–1.00, B–1.50; Galvanometer, tangent, C–3.25, B–10.00, A–15.00; Galvanometer, astatic, C–3.25, B–8.00, A–15.00; Resistance coils, C–4.00, B–6.00, A–10.00. Double connector, –.12; Contact key, C–1.50, B–2.50, A–5.00; Wheatstone's bridge, C–3.00, B–6.00, A–8.00; Wire for connection, –.10.

*40. *To measure the electrical resistance of a battery:—(a) By reduced deflection* (91). *(b) By Mance's method* (92).
App.—Commutator, C–.50, B–.75, A–4.00; Battery, etc., of No. 39.

*41. *To prove Ohm's law.*
App.—Battery of No. 39; Gal. of No. 39; Bridge of No. 39; Key of No. 39; Resistance Coil of 5000 ohms, –1.00.

*42. *To measure the electromotive-force of a battery—(a) By constant resistance* (96). *(b) By Wheatstone's method* (97).
App.—Leclanché battery, C–.65, B–1.00; Battery, etc., of No. 39.

43. *To measure the electrical resistance and the electromotive-force of two similar cells, (a) joined parallel, (b) joined in series* (93 and 98).
App.—Extra battery, C–.65, B–1.00; Battery, etc., of No. 39.

*44. *To test a tangent galvanometer* (94, 95).
App.—Galvanometer, etc., of No. 39.

SOUND.

45. *To ascertain the amount of correction due to diameter in determining the length of a cylindrical resonator* (103).
App.—Thermometer of No. 23; Metre-rod of No. 4; Caliper of No. 4; Tuning-fork, C = 256, C–1.00, B–5.00, A–8.50; Three metal tubes, C–1.50, B–2.50.

*46. *To measure the velocity of sound, (a) in air, (b) in glass* (104 and (105).
App.—Glass tube, 100 cm. long, 3 cm. diameter, –1.50; Rubber tubing, –.40; Caliper, Thermometer, and Metre-rod of No. 45; Glass funnel of No. 23; Kundt's apparatus complete, –3.00.

47. *To measure the vibration-rate of a fork by means of a resonating air-column* (108).
App.—Same as No. 45.

*48. *To verify the laws of strings* (111).
App.—Sonometer, C–2.50, B–4.25, A–10.00.

LIGHT.

49. *To study the principles governing the formation of images through small apertures* (113).
App.—Lamp, kerosene, –20; Two wooden screens, –.50.

50. *To measure the candle-power of a lamp:—(a) By Rumford's method* (115). *(b) By Bunsen's method* (116).
App.—Lamp of No. 49; Metre-rod of No. 4; Candle, –.10; Photometer screen, –.10; Screen of No. 49. Photometer table complete, –10.00.

*51. *To verify the law of reflection of light* (117).
App.—Plane mirror, –.20; Four darning-needles, –.10; Protractor of No. 5.

*52. *To measure the angle of a triangular glass prism* (118).
App.—Protractor and needles of No. 51; Triangular glass prism, –.40.

*53. *To prove that the image and object are equally distant from the plane mirror* (119).
App.—Same as No. 51, together with dividers and scale of No. 1.

*54. *To measure the principal focal distance of a concave mirror* (120 and 121).
App.—Lamp and screens of No. 49; Metre-rod of No. 4; Concave mirror, C–.50, B–3.00, A–5.00.

*55. *To measure the index of refraction of (a) water, (b) glass* (126 and 127).
App.—Refraction app., C–.75, B–5.00, A–25.00; Prism, Protractor and Needles of No. 52.

*56. *To measure the focal distance of a convex lens* (128 and 129).
App.—Convex lens, –.50; Screens of No. 49; Metre-rod of No. 4.

LABORATORY WORK IN THE SMALL HIGH SCHOOL.

MR. F. A. OSBORN, OLIVET.

Read before the Conference in Physics, March, 1898.

In discussing the question before us, I did not wish to speak of a theory but of a condition, and in accordance with that desire, I sent the following list of questions to one hundred and fifty of the smaller schools in this and adjoining states; replies have been received from about one hundred and twenty schools:

1st. Do you have individual laboratory work?
2nd. How many experiments are worked by each student in a year?

3rd. How many of these experiments are quantitative in character?

4th. How many of these experiments are qualitative?

5th. How much time per week is spent in the work?

6th. What is the average size of the class?

7th. What do you consider the greatest difficulty in the way of your doing laboratory work?

8th. Any information you can give in regard to the subject.

In answer to:

1st. 50% of the schools answer yes; 40%, no; 10% report no work of any kind.

2nd. From 15 to 200.

3rd. From 15% to 70%. These represent the lowest and highest values given.

4th. From 10% to 50%.

5th. From one to four hours.

6th. Twelve.

7th. 70% report lack and cost of apparatus; 20% lack of time; 10% lack of room.

I believe that by considering these replies in detail we shall get a fairly correct idea of the condition of our small high schools in this respect.

In reply to the question "Do you have individual work?" nearly one-half answer no. In quite a large number of cases I received letters saying that it was the custom for the instructor to perform the experiment, *the pupils taking full and complete notes*. In a few instances the pupils took turns in performing the experiments, their class-mates, as before, taking a record of them. The significant thing about these replies is, that in all cases except four, the writers thought that the above methods constituted laboratory work. In the four exceptions, lack of apparatus or time was given as the reason for using this method.

It would seem, that notwithstanding the amount of discussion devoted to laboratory work during the last few years, there are in this and the adjoining states a large number of teachers of physics who are either ignorant of the true value of laboratory work, of, if intelligent upon the subject, they allow indifference or seeming difficulties to keep them in the ways of twenty years ago. We have seen the universities and the colleges putting such requirements in mathematics, languages, and history upon their students, that teachers of these subjects have been compelled to keep in touch with the very best methods. We find, on the other hand, students coming from these same schools poorly prepared in science, and as a result handicapped in their science work in college.

It is not more than three years ago, that a speaker before this Conference said: "In order to accomplish for the student all that is most valuable to him, the work of the physical laboratory should be *largely if not wholly quantitative in character.*" A glance at the summary of replies shows that not more than one-half the problems are quantitative, and in too large a number of cases the qualitative problems form nearly three-fourths of the total number. I cannot attribute this condition to a lack either of apparatus or time, but rather to ignorance or indifference on the part of the teacher as to the real value of quantitative work.

One school worked 150 problems, of which 125 were qualitative. Another reports that "pupils have no interest in problems requiring exact measurements, and therefore eighty per cent of the problems assigned are qualitative

in character." The report might as well have said that for real training, eighty per cent of the work is practically worthless. Again, one writer informs me with pride, that during a period of ninety laboratory hours, his class worked seventy qualitative and sixty quantitative experiments! Do not these facts warrant the statement that a large amount of our laboratory work in physics is lacking in disciplinary value?

I was surprised in reading the replies to the question, "What do you consider the greatest difficulty in the way of your doing laboratory work?" to find that nearly three-fourths of the schools report lack and cost of apparatus. But I found that this answer had many meanings. For instance, one high school reports, "Board stingy; impossible to get money for a laboratory." But in the case of this very school, it has come to my knowledge that it recently invested $350 in a combination of nickle-plated pulleys, polished base-boards and mechanical toys, all neatly labelled and numbered. A student can take numbers 17, 16, 89 and 23 and produce a steam-engine; or numbers 15, 9, 104, 228 will give him the apparatus for experimenting on the pressure of liquids.

One report says, "We are well equipped with an air-pump, a frictional machine, and an induction coil. Our Board could give us but $35 this year so we are going to purchase a thermopile and a barometer. Hope next year to get some money for a laboratory."

Another reply says, "We have a chemical laboratory costing $125.00 but think the cost of a physical laboratory will be too much for us." These replies indicate, in a way, the various reasons why lack of apparatus is a great difficulty. Teachers do not know just what apparatus they need, where to purchase what they need, nor the cost of a working laboratory. I believe the plea of lack and cost of apparatus ought to be disregarded, for I am certain that it is not the greatest difficulty with which the teachers have to contend. I submit simply as a proof of the above assertion, the following list of apparatus at a total cost of $25. It is not given as an ideal list, nor even as the best list, but it is offered as a guide to the teacher earnestly desiring to know what it will cost to start a laboratory and what problems may be worked. (See page 39).

About one-fifth answering the 7th question, state that lack of time is their greatest difficulty. When we recall that teachers in the smaller high schools are required to teach six or eight classes per day, in from four to six different subjects, I think that we can realize that here is a real difficulty. If the teacher is desirous of doing laboratory work, however, it is possible, I believe, by placing the recitation hour in physics the last hour in the afternoon, to gain forty-five minutes once a week, at least, by having but four recitations per week, and the laboratory hour may be made of real value by continuing the work for forty-five minutes after school on two days in the week. This is the plan followed by several teachers, and there is every reason to believe that they have adopted the very best plan to convince the Superintendent or Board of the necessity of giving to the teacher of physics fewer class recitations. Lack of suitable room is urged by a few teachers, but I doubt if this is a very serious difficulty even in the minds of those who gave it. Granted all the other conditions, the question of room will settle itself in the majority of cases.

To sum up the facts, it seems to me that a large number of the teachers are either ignorant of the true nature and value of laboratory work, or indifferent; that the relative importance of quantitative and qualitative problems is

not fully realized; that lack of apparatus is simply an excuse, the true answer being poor judgment in buying apparatus and ignorance of the actual cost of good apparatus and of where it is to be obtained.

In closing I should like to state briefly what the Conference can do to change this state of things, and what the University and colleges can do. Every year for the past three or four years this Conference has had presented to it valuable and helpful papers along the very lines the teachers of physics need. Every objection that has been offered for not doing laboratory work has been answered here, and many helpful suggestions have been brought out. But because these discussions and papers have not found their way into the hands of the teachers much of their usefulness has been lost. Therefore I would urge upon this Conference the publication of its papers and discussions and the distribution of them to the teachers of the state. No teacher can then shield himself behind his ignorance.

In considering what the University and college can do, I hesitate to advise, for I have no doubt that the authorities have given the subject careful consideration; but it seems to me that if our high schools are to have strong work done in physics, it must be because no student can enter college without it. Laboratory work of a definite quantity and quality should be required. Again, while giving to the student the very strongest course in physics, the college ought likewise to give him special training in a teachers' class, where all these difficulties could be met and cleared away. Some will reply that the bright student will overcome all these difficulties himself as soon as he begins to teach. My answer is that in some cases he does not do so; he fails. In others he succeeds, but only at a great loss of time and energy. What it has taken him two or three years to work out alone, could have been given to him in his college course in one semester. Physics will have the place it deserves in our schools when the Conference, the University and the colleges all work together to help those who are teaching, to thoroughly prepare those who are to teach.

WHAT SHOULD THE STUDY OF PHYSICS CONTRIBUTE TO THE EDUCATION OF THE HIGH SCHOOL PUPIL?

BY PROFESSOR JOHN O. REED.

Read before the Michigan Schoolmasters' Club, November, 1897.

Within the past fifteen years the teaching of physics in the secondary schools has undergone radical revision. The subject, always rich in information, has risen rapidly into prominence as a means of discipline as well, and now occupies an important position in the curriculum. The physical laboratory has ceased to be an experiment; its training has been recognized as a most powerful means for securing certain definite and desirable results; and the object of the present discussion is rather to indicate the directions along which progress has and should be made in the teaching of physics, than to set forth at length the advantages to be derived from its study.

At the outset we are met with a mass of conflicting opinion as to the state of the work to-day and the prospects of its improvement. One thinks the work too much scattered; another that it is not distributed enough; one says the study is not pursued seriously enough, and another that it is already too hard;

one laments the recitation as a failure in that it does not show what the pupils do not know, and complains of the difficulty in procuring apparatus for experimental work, while another thinks we need more recitation and that we have all the apparatus we can use. Out of all this one thing is perfectly clear to me. The solution of the whole question is to be found in the capable teacher. Whether physics is to yield much or little depends first of all upon who is to teach. Even mathematics or Latin suffers from this limitation to-day and the schools have been trying to make teachers for those branches for ages. Let us not be discouraged. The recitation will be honest if the teacher be honest; it will not be a hard unrelenting grind if it be directed by a man of sense and sympathy who works himself. No teacher has smaller incentive to dishonesty toward his pupils than the teacher of physics and no one is so absolutely sure to be found out. He must be a man who has the honesty and manhood frequently to say he does not know, because he stands with his pupils before many problems that are not as yet even approximately solved and humility must result. Now there be teachers whom I have seen teach, not teachers of physics either, to whom this confession was like the extraction of teeth; instead of saying frankly and honestly "I don't know," they resort to the artifice of the ostrich in the desert; lead their questioner a dusty chase and finally poke their heads under the first mass of technical rubbish that presents itself and imagine themselves hid, while the truth is plain to all. My first point then would be that the contribution of physics as an educative factor is what the teacher makes it. Especially since it is a study whose effective presentation calls for such rare and varied accomplishments on the part of the teacher.

Again, the growing importance of the study of physics in the high school has emphasized the great need of teachers specially trained along scientific lines, accustomed to scientific methods and thoroughly imbued with the spirit of laboratory study. This does not mean that the teacher shall have studied nothing else but science; far from it. Unless the prospective teacher of physics shall have had a liberal education, a good knowledge of Latin, German, French, and English, unless he be well versed in mathematics and chemistry he is not in a position to command the fullest measure of success. It does mean, however, that unless there be superposed upon this basis of liberal culture a specific scientific training running through three or four years of actual contact with and work in the physical laboratory; together with extended work in chemistry and mathematics, he is not competent to stand as a representative of this the most valuable science in the high school. General education alone, however thorough, will not answer; much less will a sound classical training fit a man to undertake the teaching of any branch of knowledge whatsoever, be it physics or history, chemistry, botany or French. Each line of study has characteristic requirements and demands for its best presentation a specific training. So true is this, that prolonged study of the classics unfits a student for successful scientific work; and it is a curious and significant fact that the most common errors in the teaching of physical science are due almost wholly to the survival in this new field, of the methods of classical teaching; while *memorizing*, the unpardonable sin in science study (if we are to believe our classical friends), is begotten and fostered in the study of the classics. On the other hand, scientific methods of study, of laboratory work and of vivid illustration through contact with things, have been so completely adopted and paralleled in the archeological, sociological, ethnological, classical laboratory, and the cry for illustrative material in the form casts,

photographs, magic lantern pictures, etc., has grown so loud that we await with some trepidation the claim that all that is good and wholesome in science study is not only to be found more abundantly in classics, but in reality never existed anywhere else.

Now while granting all that may be claimed for classical studies as a means of discipline, and as a means of promoting mental acumen and developing strength and mobility of mind, it is by no means conceded that this drill and discipline is all that is needed for any mind, much less that it is the best for every mind. No one would advocate more heartily than I the beneficial effects of Latin and Greek when judiciously and thoroughly taught; on the other hand I believe no system of training can be made more pernicious when the study of these subjects is made to presuppose the exclusion of every other form of mental activity, together with the assumption that there are but two classes in the world of letters: those who know only Latin and Greek and the unwashed throng who presume to know anything else. It is this narrow view that demands the intellectual brick without furnishing the necessary straw; that claims for classical studies alone the virtue of producing acuteness and strength of mind and in the same breath demands that the requirement of physics in the high school be remitted to students in the classical course as it is "*too hard for them to learn.*" To this purblind narrowness of mental vision on the part of some principals and superintendents is due in great part the difficulty in establishing science teaching upon a firm footing in our schools and in realizing from the study of physics its fullest benefits. This brings me to my second thesis: The study of physics will contribute much or little to the education of the high school pupil according as it is given an equal or a subordinate place in school as compared with other studies. This is no unheard of thing. The subjects may appear upon an equality in the course of study and may seem each to claim its proper amount of attention and yet, according as the principal or superintendent of that school may elect, this equal balance may be preserved, or the teacher in Latin, Greek, history or mathematics may be allowed to monopolize the time and energy of the pupil to the practical exclusion of other subjects.

But putting aside the evils of the present, what should the study of physics contribute to the education of the high school pupil? It is common to consider a subject of study as yielding information, discipline and culture, or some combination of the three, according as its pursuit forms or informs the mind, or causes it to take on a firmer texture and a more sprightly habit from the combined effect of formation and information. Let us consider the effect of the study of physics from each of these aspects.

First, as to the informational side: Need I enumerate the magnitude or grandeur of the subject matter of the study of physics, or paint the intimate relation such study must establish between the young and growing mind and its environment? Physics find its matter in the phenomena of daily life. The wind, the rain, the drop of dew, the rainbow and the lightning flash all speak to him who understands, of the endless, tireless round of change in which our lives are but a passing ripple. Not only is the natural world revealed to us through the study of its physical laws, won through long ages of patient, unremitting toil, but the world of man is closed to him who is ignorant of physical phenomena. The boy or girl who is denied a knowledge of the underlying principles of the world's greatest inventions is wronged for life. The locomotive, the telegraph, the electric light, the telephone and the dynamo, the real slaves of our Aladdin's lamp, the burden bearers of our modern life, so

complex in appearance and yet in principle so simple that he who runs may understand, shall these meet us at every step, every day of our lives, and provoke no thought? Shall we see, and yet seeing fail to understand? The proper study of mankind is not man alone, but *man and nature*. A knowledge of each and of their mutual relations underlies all sanity of judgment. This knowledge is the birthright of every competent mind. Tho boy or girl who for any reason whatsoever is denied or wheedled out of the time necessary for its acquisition suffers a wrong which the law should redress.

But if it be granted that the study of physics is rich in possibilities of information beyond "that which eye hath seen or ear heard," still there comes the question what does it furnish as discipline? Can you drill in physics? How much mental exertion can you produce in a given time? Here also the advocate of our science as an educational factor need not be ashamed. Let us examine the facts. At the outset the pupil meets a vocabulary as new, as exact and as persistent as that of the Latin reader. The words are not only for the most part new, the ideas are almost entirely so. The concepts of force and momentum, of energy, inertia, acceleration, velocity and work, are so fundamental, so clear-cut, and so far-reaching, that nothing short of constant drill, repeated use and exemplification on the part of the pupil, can fix them firmly in mind. These scientific terms, these fundamental concepts are met at every step; no page of physical literature can be found on which some of them do not occur. These ideas and relations are fundamental; this technical nomenclature forms the very alphabet of the science and without it nothing can be done. Now, whether it is better that these ideas and their relations be developed and explained to the student, or that he be set to discover them, or lastly that the teacher should proceed to *evolve* them out of the vacuous spaces of the student's inner conscionsness, (as I have seen some well-meaning but misguided teachers attempt to do,) this is not the place to discuss. These ideas and their mathematical and physical relations must be mastered; they must be reviewed, and reviewed, and reviewed. Finally they must be brought to the crucial test through the solution of problems involving their application. These formulæ, constituting the mathematical expressions for the fundamental physical laws are much more simple than the formulæ of elementary mathematics, and have the additional advantage of applying directly to the phenomena of every day life; and the mental discipline that comes from their mastery is, I firmly believe, superior to that furnished by algebra or geometry. The formula becomes living; it is no transient guest; it will not down; it comes and stays and will not go away. It appears at the most unexpected times and places and connects motion, heat, light, sound, electric and magnetic phenomena through the common bond of equivalent energy.

So fruitful a field for the discipline derived from mathematical manipulation can be found no where else in the entire range of science. So far from there being a lack of such opportunity, one of the most important questions to be decided by the author of a text-book on physics is just where to draw the line between the mathematical and the experimental treatment of natural phenomena. The two extremes of this question are interesting; on the one hand we find those melancholy preparations of scientific gruel dispensed in homœopathic doses, containing the minimum of scientific truth suspended in misstatement and wishy-washy talk, and adapted to the use of young ladies finishing schools and institutions for the feeble-minded. The other side of the shield shows the mathematician rampant upon a field of fact. The treat-

ment is decided from the point of view of its mathematical applications. Physics is no longer taught for itself or for the truth it represents but to furnish an additional drill and parade ground for mathematical gymnastics. In either case the true balance is lost and the subject suffers accordingly.

But the benefits derived from a study of physics do not stop at the possibilities of formal discipline and mathematical drill. I think I am justified in saying that this is the least benefit to be urged, however great that may be. This may be derived from the study of the text alone. The greater benefit comes from the laboratory practice. The effects of systematic laboratory instruction are both tonic and specific. Tonic in that it vivifies and intensifies the subject matter of the text, gives a reality and as it were an element of personal acquaintance to the facts already accepted as truth. Specific in that it corrects radically, if applied in time, certain attitudes of mind in the average student and awakens the healthful influence of a reasonable doubt. These efforts may be best discussed perhaps, under the following heads:

a. Physical training or manipulation.—The student in the laboratory is brought face to face with conditions which he must vary and control. There is something for him to do. He must use his hands and be responsible for the result. He must acquire a certain technique, a deftness and certainty of touch, an ability to handle and adjust apparatus, which, however small it may seem to be in itself, forms one of the characteristic differences between the civilized man and the savage. The student who has learned to handle a spherometer or a vernier caliper properly, who can measure the focal length of a lens without dropping it upon the floor, who can adjust and operate a balance or a spectroscope without tearing either of them to pieces, in short who can take up and use any piece of apparatus in the laboratory intelligently, and when done replace it where it belongs in as good condition as he found it, has made an acquisition for life. Immediately connected with this acquirement comes one even more important; the ability to work systematically and methodically, to record results carefully and at the exact time of observation, to record what he sees, to keep things together and in order, and to leave a record that will be intelligible after the circumstances of the experiment are entirely forgotten. To do this the student must have the direct oversight and example of the instructor. Here as elsewhere, the force of example is all powerful, and a teacher who is careless and unmethodical, who drops things just where he uses them and looks for them where he last saw a student have them, who is noisy in speech and slovenly in management, who comes late to the laboratory and goes early, leaving it looking as though it had been the scene of a tornado or a railroad collision, is one of the most efficient agencies for evil that modern science knows. Such a laboratory is a curse to the school that has it and such teaching is villainous! Pray you avoid it. Here it is of all things important that the teacher be himself an experimenter and an investigator. No amount of theorizing nor philosophizing will replace the need of a guide who has been over the road; who can take hold and bring a refractory piece of apparatus to terms; who knows how to record results himself and sees to it that it is done and that habits of neatness, accuracy and method are firmly established.

b. Mental training.—A still more important effect is the implanting of distinctly new ideas. The student for once finds a subject entirely busied with the reason of things. If, as Kirchoff declares, the business of physics be the accounting for all natural phenomena in the simplest possible manner, then one of the fundamental benefits of a study of physics is that

the student acquires firmly the idea of causality. Things do not happen, they are caused. Life is no longer subject to the caprice of illnatured divinities, but is a series of phenomena every one of which has definite causes, which, operating under exactly similar conditions must always produce the same result. The question, what causes it, or what makes it, is one repeated by every healthy child many times a day. Physics answers those questions and reawakens in the pupil's mind the idea of causality, and an interest *in things*—provided he has not been too long under the influence of Latin Grammar—in which case he relies upon authority and does not care to know the cause of anything. Why? He expects to learn his Latin lesson and to recite when called upon; if anything new or strange makes its appearance he looks first in the vocabulary, then in the notes, and then in the grammar; if it is not there he has exhausted his resources. Help must come from some one of these sources or a combination of them. Now it is the province of the physical laboratory, and the instructor in physics, to correct this state of mind, provided it be not a case of too long standing. I have seen pupils so engrossed in Latin and Greek that the most striking experiment failed utterly to arouse their interest; they sat in class like so many wooden Indians, they were intellectually *blasé*. The only thing that produced any noticeable effect upon them was a discharge from a Leyden jar. Such an unnatural attitude of mind can only arise from a mistaken idea of relative values, and is fostered by narrowness not to say bigotry on part of the teacher. It is the ideal function of science study on the one hand and of linguistic study on the other, so to awaken and preserve the interest of the pupil, that each heightens by contrast the effect of the other. In so far as the teaching in either branch fails to do this, in so far is it false and pernicious. The aim of the high school is to produce intelligent citizens rather than wild-eyed specialists.

Again, the pupil must soon become aware of the fact that many, very many of the statements in the book are only approximately true, and if he be really acute he will discover for himself, through experiment, that some of them are not true even approximately, under the conditions of his investigation. In other words, he gains through experience an idea of the degree of attainable accuracy in many cases. He finds that almost without exception the more refined the apparatus and the greater the care taken in the experiment the more certainly does he discover minute deviations from the expected results. These deviations arise from a multitude of causes whose effects, with less sensitive apparatus were not apparent. It is necessary therefore for the pupil to learn very early in his course that results *may* differ from the values given in the book and yet indicate very good work indeed. The necessity for varying the conditions to exclude one after an other the supposed sources of error, for repeating the experiment under the *same* conditions for purposes of comparison, these are lessons that can not be learned too soon nor impressed too deeply. As a result, the pupil gains confidence in his ability to observe for himself, to compare and check his results and to determine for himself the degree of dependence to be attached to them. This is by no means a small thing. One of the surest sources of trouble for the beginner is his absolute lack of confidence in his own results. If another finds a different value, his must be wrong; that is the inevitable conclusion; and the student who has learned to hold fast to his own results until he is convinced, from redeterminations, that they are wrong, and has found *why* they were wrong, has solved one of the most important problems of his life, and this brings me to the third and most important effect of laboratory practice.

c. Character effect.—The crowning glory of science work is the production of the scientific conscience. The student who sets out to find the density of lead, or the time of vibration of a pendulum desires simply to know the truth of the matter. His object being the truth, what possible reason can there be for his preferring one result to another provided each be equally credible? So soon as he is disenthralled from the authority of the book and made to see that he is responsible, and responsible to himself alone for the performance of the experiment in the best manner possible, we have, it seems to me, the highest possible incentive for honest work. He must also be warned against forming a prejudice in favor of one value as compared with any other unless there be some weighty reason for such preference. Absolute indifference as to what the result is to be, unflinching honesty in dealing with the results, and patient revision and verification of the values found, these are the ideals to be held up for laboratory work. Certainly not how much, nor how rapidly, but how well and how thoroughly. And now I may ask—What must be the lasting effect of such training if conscientiously carried on under the best conditions obtainable? The student who has learned that the true test of knowledge is experiment, that the value obtained from a single determination of any physical quantity is only an indication more or less reliable as to what the true value is, that all results are to be treated as equally valuable unless disproved by repeated experiment, that descriptions of observations are above all things to be clear, explicit and minute, since often it is the unobserved and unsuspected trifle that sets our work by the ears, that all determinations and all instruments and all observers are liable to error and are never perfect,—the student who has come to have a realizing sense of these facts in the laboratory has gained at the same time a most valuable criterion for his future actions in life.

His type of mind will surely not be characterized either by unquestioning credulity or by bold and unwarranted assumption of knowledge he does not possess. He will be inclined to look for proofs before accepting any statement as a fact, and while not oppressed by humility he will not be offensive in the expression of his opinions. Knowing as he does that in nature at least it is physically impossible for something to be gotten without an equivalent, that the account is at all times made to balance, he will neither be visionary nor despondent, and last and best of all he will be willing to admit that there are many things of which he knows nothing. I can not close this paper better than by quoting the words of Professor Rowland.

"But, for myself, I value in a scientific mind most of all that love of truth, that care in its pursuit, and that humility of mind which makes the possibility of error always present, more than any other quality. This is the mind which has built up modern science to its present perfection, which has laid one stone upon the other with such care that it to-day offers to the world the most complete monument to human reason.

This is the mind which is destined to govern the world in the future and to solve problems pertaining to politics and humanity as well as to inanimate nature. It is the only mind which appreciates the imperfections of the human reason and is careful to guard against them. It is the only mind that values the truth as it should be valued and ignores all personal feelings in its pursuit. And this is the mind the physical laboratory is built to cultivate."

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The first part of this book, as indicated by the title, consists of Laboratory Notes for a Beginner's Course in Quantitative Analysis. It considers the subjects of Gravimetric and Volumetric Analysis, for beginners, by means of the chemical analysis of a set of substances properly numbered, in each case giving the methods to be followed in such analysis; also the methods for calculating and preparing volumetric standard solutions, generally following the course offered by Professor Cheever to his students. It also considers the methods for the determination of the specific gravities of various liquids and solids.

Although a number of the analyses contained in Part I. may be of only approximate accuracy, and of small commercial value, such are yet included with a special purpose, to wit:—that they may supply the student with a wider range of work and a greater diversity of chemical manipulation. This was Professor Cheever's idea, and it is certainly a good one, especially since, in most cases, the work of the beginner simply serves to emphasize the necessity of careful scrutiny of details and methods for practical work in the future.

Part I. is offered, then, for the use of schools and colleges, and it is intended to supply a source of elementary information upon the subject of Quantitative Chemical Analysis rarely offered in such form in works upon that subject.—Preface

The author was for many years Professor of Metallurgy in the University of Michigan, and the methods here presented are those mostly offered by him to his students. As a beginner's book in quantitative analysis, it will be found eminently practical, and it can be honestly recommended to the student who desires a source of elementary information upon this branch of applied science. The book is divided into two parts, the first consisting of laboratory notes for beginners. The subjects of gravimetric and volumetric analysis are considered by means of the chemical analysis of a set of substances, properly numbered, in each case giving the methods to be followed in such analysis, and also the methods of calculating and preparing volumetric standard solutions, etc. Methods for the determination of specific gravities of various liquids and solids are also considered.

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The determination of the motions of the heavenly bodies is an important problem in and for itself, and also on account of the influence it has exerted on the development of mathematics. It has engaged the attention of the greatest mathematicians, and, in the course of their not altogether successful attempts to solve it, they have displayed unsurpassed ingenuity. The methods devised by them have proved useful, not only in this problem, but have also largely determined the course of advance in other branches of mathematics. Analytical mechanics, beginning with Newton, and receiving a finished clearness from Lagrange, is especially indebted to this problem, and in turn, analytical mechanics has been so suggestive in method as to determine largely both the direction and rapidity of the advancement of mathematical scienoe.

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The seoond part of the book is devoted to methods for laboratory work: softening, hardening, decalcification, etc., of the matter in gross; embedding, sectioning, staining and mounting, etc. The best stains, with methods of preparing the same, and, in short, a general formulary for the various reagents, etc., concludes the work, which is intended, as stated, as an *aide memoire* supplementary to a course of lectures on histology.

We congratulate Dr. Huber on the skill with which he has developed the idea, and the didactic methods which he has employed. Such a book cannot but prove a great help to both student and teacher, and it should be more widely known —*St. Louis Medical and Surgeon's Journal.*

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While the book is manifestly designed for the use of Dr. Novy's own students, we doubt not that other teachers will find it a valuable aid in their work. At the close of the volume are a number of illustrations of the various sedimentary substances found in the urine, taken from the work of von Jaksch.—*The Therapeutic Gazette*

This book, although now in its second edition, is practically unknown to British readers. Up to the present, anyone wishing to find out how a particular analytical method in physiological chemistry ought to be carried out, had of necessity to refer

to a German text-book. This comparatively small book—for it only covers some three hundred pages—gives as good a general account of ordinary laboratory methods as any teacher or student could desire. Although the author refers in his preface to help derived from the works of Salkowski, Hammarsten and others, it is but fair to say that the book has undoubtedly been written by one who has worked out the methods and knows the importance of exact practical details—*Edinburgh Med. Jour.*, Scotland.

Physiological chemistry is one of the most important studies of the medical curriculum. The cultivation of this field has until recently been possible to but few. The rapid development of this department of science within a few years past has thrown much and needed light upon physiological processes It is from this quarter and from bacteriological investigations that progress must chiefly be expected. The rapid growth of this branch of chemistry is attended by another result. It necessitates the frequent revision of text-books. The present edition of Dr. Novy's valuable book is almost wholly rewritten It is representative of the present state of knowledge and is replete with information of value alike to student and practitioner. Few are better prepared to write such a book than Dr. Novy, who has himself done much original work in this field.—*The Medical Bulletin, Philadelphia.*

This is a greatly enlarged edition of Dr. Novy's work on Physiological Chemistry, and contains a large amount of new material not found in the former edition. It is designed as a text-book and guide for students in experimental work in the laboratory, and does not therefore cover the same ground as the works of Gamgee, Lea, and other authors of books on physiological chemistry. As a laboratory guide it should be adopted by our medical colleges throughout the country, because it is an American production, contains only such directions and descriptions as have been verified by actual practice with students, and because it is clear, concise and definite in all its statements. Its first ten chapters treat of fats, carbohydrates, proteins, saliva, gastric juice pancreatic secretion, bile, blood, milk, and urine. Chapter xi. is devoted to the quantitative analysis of urine, milk, gastric juice, and blood, while chapter xii. gives tables for examination of urine and a list of reagents.—*Am. Medico-Surgical Bulletin, N. Y.*

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This book was issued from the press under the author's careful supervision. Professor Watson was noted for his clear insight into problems involving computations, and also for his wonderful ability in presenting the method of sclution of such problems in a plain and simple manner. The varied array of practical examples given in connect on with his "Table" shows these facts in a remarkable manner. This book provides, for those least expert in calculations, the means of avoiding mistakes likely to occur; and for the man engrossed in the cares of business, the means of making for himself, with entire accuracy, the calculation which he may need at the moment when it is needed.

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